A Summary of Current Program, 4/1/63 and Preliminary Report of Progress for 4/1/62 to 3/31/63

SOIL AND WATER CONSERVATION

RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program view and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between April 1, 1962, and March 31, 1963. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Soil and Water Conservation Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland.

UNITED STATES DEPARTMENT OF AGRICULTURE
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INTRODUCTION

Soil, water, air and sunshine are vital national assets--the very foundation of human existence. How these four interrelated natural resources are used in agriculture determines the extent to which mankind's primary needs for food and fiber are met. How these resources are conserved, developed and managed greatly affects the economic growth and strength of the nation and its role as a leader in world affairs.

Conservation involves the maintenance of the productive capacity of our soil and water resources, and the development or improvement of productive potentials to the extent needed by future national requirements. The conservation and economic management of water in agricultural uses is critical for the balanced growth of all water-using industries and the entire economy. As one of the largest users of water, agriculture has a responsibility for its conservation, its efficient use and for avoiding waste. To meet the needs of the rapidly increasing population, and to offset the loss to agriculture of over a million acres of land a year for urban and industrial development, recreation and superhighways, it is imperative that the search be intensified for fruitful avenues of further increasing production per acre.

The Soil and Water Conservation Research Division actively pursues many areas of soil and water research. The Division employs approximately 415 scientists, covering 17 widely varying disciplines. Its nationwide program is organized for convenience and efficiency into three main categories: (1) watershed engineering research; (2) water management research; and (3) soil management research. Information on these subjects is gathered through the activities of seven branches, organized by geographic regions. There is one Pioneering Research Laboratory--the Mineral Nutrition Laboratory--located at Beltsville, Maryland. The following seven national laboratories are incorporated into the various branches: U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, New York; U. S. Sedimentation Laboratory, Oxford, Mississippi; U. S. Salinity Laboratory, Riverside, California; U. S. Water Conservation Laboratory, Tempe, Arizona; and U. S. Soils Laboratory, U. S. Fertilizer Laboratory, and U. S. Hydrograph Laboratory, Beltsville, Maryland. All these, plus approximately 100 field locations contribute to the Division's research program.

Although many problems of soil and water conservation have already been solved through research and experience, those facing the nation today are of the highest possible complexity and difficulty, and as such will require even greater input of resources for solution. In presenting this progress report, the work is grouped into 13 areas which correspond to the Division's 13 work projects. The problems of the future will require greater efforts and better facilities. The rapidity and permanency of solution to such problems will depend in large measure upon the effort expended.

Outstanding Accomplishments

1. Method for predicting wind erosion severity.

A method for predicting the severity of wind erosion conditions in any region of the Great Plains at least seven months in advance of their occurrence has been developed at the Soil Erosion Laboratory at Manhattan, Kansas. The method employs computation of an erosion index based on temperature, precipitation, and wind velocity for a three-year period ending May 31 to serve as an index of relative severity of wind erosion conditions during the forthcoming calendar year, January 1 to December 31. If the index exceeds a critical value, a recommendation could be made to farmers to take special precautions to control wind erosion. Much damage to crops and soils in the past has been due to farmers being unaware of impending dust storms. Now they can combine a prediction with their own judgment and knowledge on what to do to control wind erosion most effectively. On the basis of analyzed data, a prediction of whether the severity of wind erosion conditions would be above or below a critical value will be accurate about 85 percent of the time.

2. Muscular dystrophy in livestock is associated with low selenium in soil-parent material.

At the U. S. Plant, Soil, and Nutrition Laboratory, Ithaca, New York, the selenium content of forage crops from different areas has been measured and found to substantiate the pattern predicted on the basis of the geology of the soil-parent material. The map developed by the laboratory shows that muscular dystrophy is rare in regions where the soil-parent material contains seleniferous Cretaceous sediments of west-central United States. The disease is common to the south and east of the Great Lakes and in areas in the Pacific Northwest where the soils are formed on young volcanic materials.

The selenium content of forages collected from areas where muscular dystrophy has occurred were uniformly low. Samples collected in western New York, central Oregon, and the Carson Valley of Nevada all contained less than 0.1 ppm of selenium. Samples from western Iowa, Nebraska, western Minnesota, and Missouri, where the white muscle disease is rare, contained from 0.15 to 0.80 ppm of selenium.

These results suggest that the use of selenized fertilizers to increase the selenium content of forages may be a potential method for prevention of muscular dystrophy in the problem areas. An evaluation of two experimental selenized fertilizers is underway at the laboratory.

3. Study of rainfall improves design of irrigation systems.

A simple procedure for estimating how much of the rainfall on irrigated lands is effective in reducing the needs for irrigation water for crop production has been developed by the U. S. Hydrograph Laboratory at Beltsville, Maryland. Assuming that adequate evapotranspiration data are available, this procedure makes it possible, when irrigation projects are being designed, to more accurately balance the water requirements of the area against the available supplies from storage, diversion, or pumping. Rainfall data furnished by the U. S. Weather Bureau for all parts of the country were used in the analysis, thus the procedure is applicable to all of the conterminous United States.

4. Large leaf area important in cotton production.

More efficient use of incoming solar radiation holds promise for conservation of moisture resources in Alabama, Georgia, South Carolina, and Virginia. Increased energy capture in the canopy of tobacco and cotton was made possible by controlling leaf areas. This resulted in using more solar energy in photosynthesis and less in evaporating water.

These investigations showed, however, that four to six acres of leaf area per acre of land area were desirable in cotton by July 1 and that if not attained until September 1, they adversely affected the crop--July and August being critical months in the growth of cotton.

In addition to plant spacing and fertility control to adjust leaf area of tobacco, genetic material capable of using the entire growing season was essential. The annual loss of water per acre by evaporation in part-season varieties was higher than in full-season ones.

These studies further suggest that in addition to capture of energy from the sun, leaves can dissipate energy from rain and reduce erosion hazards in the area where climate offers the highest erosion potential of any area in the country.

5. Water retention by stratified soils.

Procedures for control of profile storage of soil moisture are being investigated in the Columbia River Basin. Investigations have shown that a layer of coarse material at the bottom of the root zone resulted in 2.3 times as much profile storage of available moisture as would be expected without such a layer. A coarse layer in the profile has such low flow characteristics, when unsaturated, that the profile behaves as if it had a perched water table on top of the coarse layer. For this reason, field capacity is reduced to a much lower tension. The drier limit of the available moisture range was not greatly affected. In areas where soil topography is altered to increase efficiency of application of water, these studies suggest that storage efficiency might also be increased.

6. Design criteria developed for low-gradient border check irrigation systems.

At Mitchell, Nebraska, a theoretical equation was developed for predicting the uniformity of irrigation in a border check irrigation system, and field data on performance of low-grade border checks have verified the equation. This equation was designed to remove much of the guesswork in the design or "rule of thumb" procedures now used for selecting the slope of low-gradient border checks. This equation is an important step in providing for field application, a means of more fully utilizing the theoretical advances in irrigation hydraulics with a resultant increase in water application efficiency.

7. Water flow in soils estimated by new theory and equipment.

Improved methods of measurement have markedly increased the possibilities of applying soil physics advances to water management problems in Illinois and Iowa. Straingage pressure devices for measurement of energy of water retention and improved gamma ray procedures for measurement of water content have been developed. Adaptations for use on small watersheds have been made and preliminary measurements have shown that computer programs using such data can predict watershed behavior.

These advances also enable scientists to follow moisture movement through the soil into the root zone and into ground water. They should be of marked value in developing improved practices and facilities to assure optimum root zone moisture control and provide valuable guides for management of underground aquifers.

8. Clay in streambanks influences their stability.

Fundamental studies of the soil materials of streambanks and the banks of ditches have shown that the amount and type of clay in the material is a key factor that determines how well the banks will withstand the erosive forces of the streamflow. The laboratory studies were carried out at the U. S. Sedimentation Laboratory at Oxford, Mississippi, on more than 1200 samples of streambank materials. The basic theories developed in the Laboratory will be checked against field observations of streams and channels in Florida, Arkansas, Georgia, Texas, Iowa, New York,and elsewhere to develop field procedures for assessing the erodibility of streambanks and developing criteria for control works for the many thousands of miles of eroding streambanks in the United States.

9. Efficiency of moisture use by corn increased by adjusting management.

Studies in western Minnesota and eastern South Dakota show that soil moisture can be utilized more effectively by corn if plant population, fertilizer, and other management levels are adjusted to the available soil moisture supply in the border area between arid and humid regions of the United States. While soils in the area have a moisture storage capacity of about 12 inches, soil moisture at planting time ranged from 1 to 14 inches. The probability of the soil moisture reserves being recharged by rainfall after planting are remote. Corn yields for 3, 7, and 11 inches of stored soil moisture were 43, 77, and 96 bushels per acre, respectively. With 11 inches of stored moisture, 20,000 plants per acre were required for maximum yields, while only 8,000 plants gave the highest yield with 3 inches of stored water. The extent to which fertilizer amounts should be lowered with extremely low soil moisture supplies or raised with high soil moisture are being clarified.

10. Mobile radio system and radar facilitate timely collection of hydrologic records.

A radar system recently installed at the Walnut Gulch Experimental Watershed near Tombstone, Arizona, is being used as a warning system in connection with vehicle mounted two-way radios to deploy the staff to areas of critical needs. Timing is most important in this hydrologic program.

The radar shows the scientists the location of the precipitation on the experimental area. Using a two-way radio system, the staff is then sent to strategic locations to collect valuable research information. After completing his inspection, the scientist by using his two-way radio can then determine where his assistance will most be needed.

Runoff often starts only a few minutes after the precipitation starts and lasts only a few hours. The sediment carried by the runoff must be sampled from the beginning of the runoff hydrograph. The operation of water level recorders is checked for accuracy and completeness and sediment samples are collected during the critical time of storm periods. The warning system helped the scientists to correct as estimated 10 percent hydrologic instrument malfunction. Suspended sediment samples were obtained in numerous instances where the warning enabled the staff to arrive at strategic locations on time.

The radio system is also a valuable safety tool. Scientists working in remote portions of the experimental area are now in contact with the laboratory or another vehicle during times of need.

11. Movement of water and nutrients around bands of soluble chemicals in soil.

At Beltsville, Maryland, studies on the movement of nitrates and water around bands of sodium nitrate have shown that once the accumulating solution exceeded that which could be held by the soil, the excess soluble nutrient literally dropped out of the band under the force of gravity. When sodium nitrate was banded in a soil with moisture contents greater than field capacity, the soil water moved under the osmotic force generated to the band of sodium nitrate. The sodium nitrate then dissolved and was not able to diffuse away from the band because of the influx of water. As a result, the sodium nitrate accumulated in amounts which exceeded that which the soil could hold and the dropout occurred. This dropout continued until essentially all of the sodium nitrate had been dissolved. The movement of nitrogen below the root zone limited the plants' ability to utilize this nutrient. As a result, the efficiency of band application of nitrogen to crops like tobacco, cotton, corn, and sugar beets could be very low. Subsequent studies showed that much of the downward movement of nitrate from a band could be eliminated by placing a simple "u" shaped plastic shield under the band.

These studies demonstrate the potential of controlling the leaching of soluble nutrients from bands by the use of inexpensive plastic shields. Tests are underway in the field to examine this phenomena.

12. Soil moisture necessary for the uptake of phosphorus.

At Bozeman, Montana, studies show that the plant's ability to absorb phosphorus rapidly declines as the soil dries and that plants can get none from soils drier than the wilting point. Radioactive phosphate fertilizer was used in these experiments with wheat. After water was applied to the dry soil, the time required by the plant to take up a detectable amount of phosphorus varied with the size of the plant. At the tillering stage, 32 hours was required as compared to 5 days at the heading stage. These results suggest that the plant in dry periods must get its phosphate from moist subsoils or subsist on phosphorus previously absorbed under moist conditions. The results also show that supplying the wheat plant with adequate phosphorus up to heading and none thereafter is sufficient for maximum yields. The absence of phosphorus for 2 weeks or longer in early growth severely reduced yields.

These facts are extremely important in dryland areas with phosphorus deficient soils. In these areas, the surface soil, where the available native and fertilizer phosphorus is located, is dry a good portion of the time.

This work also indicates that the reduced availability of phosphorus due to dry soils from heading time on may not be of much significance providing that the phosphorus supplies are adequate in the spring when the surface soil remains moist.

13. Phosphate accentuates zinc deficiency in the Northwest.

Field studies on zinc deficiency of the Russet Burbank potato conducted at Prosser, Washington, have shown that increasing rates of phosphorus fertilizer applied without zinc increased the incidence of zinc deficiency symptoms on the plants. Because the zinc concentration was the same in deficient and normal plants, it appears that there is a mutual antagonism between zinc and phosphorus in plant nutrition. In the treatments that received 16 pounds of zinc per acre and no phosphorus, the zinc concentration in the plant material was 71 ppm as compared to 14 ppm on the treatment receiving the same amount of zinc plus 320 pounds of phosphorus. Similarly, where 320 pounds of phosphorus per acre were applied, the phosphorus content of the leaves was decreased from 1.3 percent where no zinc was applied to 0.3 percent at the 16 pound per acre zinc level.

These studies serve as a good example of what may happen to the productivity of a soil if the nutrient balance is not carefully considered. In soils low in available zinc, additions of phosphate can accentuate the damage caused by zinc deficiency. The maintenance of a satisfactory nutrient-element balance may well be a crucial factor in assuring the productivity of many of our soils in the future.

14. Chemical tracers provide improved research tool.

Significant improvement in the detection of chemical tracers that are used to measure the flow of water in pipes, open channels, and aquifers, has been made at the U. S. Water Conservation Laboratory in Tempe, Arizona. Field tests have shown that chemical tracers in concentrations of the order of 16 parts per billion can be measured with less than 1 percent error. When added to streams, changes in concentration can be used to measure volume of water flow. Rate of transport down the stream can be used to measure flow velocity. As well as aids to water logging these advances are of great benefit in hydraulic investigations as well as those associated with ground water management.

15. Trapezoidal flume fills need for simple on-farm water measurement device.

Studies at Fort Collins, Colorado, show that trapezoidal flumes, which can be made an integral part of a concrete-lined irrigation channel, provide nearly trouble-free measurement of irrigation water. There is a minimum of obstruction to debris carried in the water and the flume can be operated under a high degree of submergence without discharge corrections being

necessary. The flume has plane surfaces and is easily constructed, or it can be formed of metal or plastic for placement in the ditch after the concrete is set.

As intensity and efficiency of use of water resources are increased, the use of simple water measurement devices such as the trapezoidal flume will be increasingly important wherever irrigation systems are installed.

16. Sprinkler irrigation system design methods improved.

A portable irrigation sprinkler device developed in Nevada and Idaho has proved to be very useful in field trials for measuring moisture intake rates of soil, as well as uniformity of application of irrigation water. This sprinkler infiltrometer provides for measurement of infiltration on a pie-shaped area that receives water the same as it would from a regular sprinkler system. Ring infiltrometers which have been used extensively until now have given higher values for intake rates and consequently led to improper sprinkler system design. Furthermore, this device permits selection of sprinkler heads and sprinkler spacing to achieve maximum application efficiency.

This approach has already enjoyed acceptance and is used to guide the design of sprinkler systems for use on rather large acreage that is being brought under irrigation.

17. Productivity of areas depleted of surface soil as high as undisturbed soils.

Greenhouse experiments conducted at Bushland, Texas, show that the loss of topsoil from deep Great Plains soils may be compensated for by the application of fertilizers. Horizon studies of 8 benchmark soils in the Southern Plains showed that the subsurface horizons of these soils could be made as productive or more productive than the surface horizons providing that adequate nitrogen and phosphorus fertilizers are used. In a field study on Pullman silty clay loam soil at Bushland which had 12 inches of the topsoil removed, the yields on fertilized treatments were the same as on the uncut soil. On an area with 16 inches of surface soil removed, the yields were only 10 percent less than the uncut area when adequate nitrogen and phosphorus were used. Similar studies in Virginia, Georgia, Maine, Minnesota, and North Dakota have shown that cut areas respond in the same way.

If the physical condition of the subsoil is satisfactory and the soil water reservoir is not seriously reduced, the removal or shifting of topsoil to provide for establishment of such moisture conservation practices as bench leveling and other similar landforming operations can be accommodated.

AREA 1: SEDIMENTATION PROCESSES IN RELATION TO WATERSHED DEVELOPMENT AND PROTECTION

Problem. Sediment is the largest single pollutant of the nation's streams. It reduces reservoir storage capacity, clogs highway and drainage ditches, fills stream channels causing increased flooding, damages fish and wildlife, and otherwise detracts from the inherent values of riparian lands. Sediment adds to the costly cleanup following floods, and it must be removed from domestic and industrial water supplies. In many parts of the country abatement of sediment damages is one of the primary justifications for watershed protection and development programs.

Sedimentation results from erosion and the inability of the stream system to transport the eroded material. Most of the sediment burden is derived from erosion on agricultural lands and the stream channel systems in agricultural watersheds.

The processes of sedimentation are complex, and an understanding of the controlling factors is essential for the development of practices and programs for solution of sediment problems. The relation between sediment load, streamflow, land use, and watershed characteristics must be clarified through research. Improved criteria are also needed for computing the bedload movement of sand, gravel, and other coarse debris in order to understand the processes of stream channel erosion and of reservoir sedimentation.

This research seeks new and improved criteria for evaluating various sedimentation processes, for identifying sediment sources, and for developing methods for sediment control and stream channel stabilization.

USDA PROGRAM

The Division has a continuing long-term program involving hydraulic and agricultural engineers, soil scientists, soil physicists, geologists, physical chemists, agronomists, and range scientists in both basic and applied studies of sedimentation processes for the purpose of developing and proving new information useful in the solution of various sediment and stream channel problems. Cooperative studies with the State Agricultural Experiment Stations are in progress in the 17 states of Arizona, California, Georgia, Idaho, Illinois, Iowa, Kansas, Mississippi, Missouri, Nebraska, New Jersey, New Mexico, New York, Ohio, Oklahoma, South Dakota, and Texas. Other cooperators in these studies include the Illinois State Water Survey, the University of Mississippi, and Purdue University.

Concentrated research in all aspects of sedimentation is carried out at the U.S. Sedimentation Laboratory at Oxford, Mississippi, where over half of the professional personnel doing sedimentation research are headquartered. At the other locations, attention can generally be given only to the most critical problem of the region.

A total of 28.8 professional man-years was devoted to research in this area in the reporting period. Of this number, 12.7 man-years were devoted to studies of sediment sources and yields from agricultural watersheds; 3.7 to rates and processes of reservoir silting; 4.2 to mechanics of sediment entrainment, transportation and deposition; and 8.2 to stream channel morphology and means and measures for stabilization.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Sediment sources and yields from agricultural watersheds

The suspended sediment load carried by Buffalo Creek at Gardenville, New York has been reduced by about 40 percent as a result of streambank erosion control measures on only 20 percent of the streambanks of the 145 square mile watershed. The suspended sediment load of adjacent Cazenovia and Cayuga Creeks, where essentially no bank stabilization measures were installed, increased about 10 percent during the same period, 1953 - 1961. (SWC 1-a1)

At the Sedimentation Laboratory, Oxford, Mississippi, a study of sediment yields from 73 watersheds throughout the United States with drainage areas of less than 100 square miles, showed that large storms are of lesser importance than the frequent small storms in influencing the long-term sediment yield of a watershed. It was found that about two-thirds of the sediment yield was attributable to small runoff events that occurred on the average more often than once a year. This finding bears on the selection of proper criteria for design of measures for alleviation of sediment damages. (SWC 1-bE1)

Treating gullies with mulch, grasses, trees, brush dams, and combinations thereof reduced sediment production of the gullies up to 80 percent for the best established cover conditions. This observation is based on studies of three treated and untreated gully systems in the loessial hills area of Mississippi during a 5-year period ending in 1962. Sediment production from untreated gullies ranged from 1.45 to 6.77 inches per year. The lower rate was associated with an average 20-foot vertical exposure of gully surface and a low percentage of uncemented sand formation in the exposure. The high production rate was associated with an average 40-foot vertical exposure and a high percentage of uncemented sand formation in the exposure face. If permanent control of gullies can be achieved with vegetation rather than structures, substantial savings will be affected. (SWC 1-bE1)

Sediment losses from bare road cuts in Cecil soils ranged from 51 to 313 tons per acre near Cartersville, Georgia in 1962, when rainfall averaged 48 inches. With other conditions equal, rates depended on bank steepness and orientation. For example, since 1958, bare banks facing northwest have yielded 2.14 times more sediment than those facing southeast. Adjacent banks, protected by a complete grass cover, had no visible erosion for the same period. Mulching proved helpful to establish plant cover on slopes of 2 to 1. On steeper slopes, and for slow growing plants, it was a necessity. Straw mulch, at 2 tons per acre, was best. Criteria for allowable slopes are of substantial value in the design of the many thousands of miles of highways being constructed. (SWC 1-b1)

Data from the Pigeon Roost Creek Watershed and the North Mississippi Branch Agricultural Experiment Station are providing important information on the relation of sediment yields to critical sediment source areas upstream. In this region, the percentage of eroded material deposited on slopes, swales, and floodplains increases sharply with increasing watershed size with, apparently, a major change in relation between watershed size and sediment delivery ratio taking place when watershed size reaches 10 to 50 acres. Additional effort to clarify sediment delivery in these complex watersheds and to define the breakpoint in sediment delivery is being made. (SWC 1-bE1)

In 1962, sediment yield from a 481 acre conventionally farmed watershed, was seven times that from a 411 acre conservation farmed watershed at the Central Great Plains Experimental Watershed, near Hastings, Nebraska. Sediment yields for the year were 5.31 and 0.76 tons per acre for the respective watersheds. Though several more years of data are required to confirm this trend, the prospects for providing great savings in the cost of upstream structures through reduction in size of sediment pools appear very promising. (SWC 1-d1)

Sediment yields from fine-textured rangeland watersheds in western South Dakota were found to be twice those from similar watersheds with medium-textured soils, the measured average annual yields from the respective soil groups being about 7.5 and 3.7 tons per acre. Runoff from the watersheds with fine-textured soils is about four times that from the watersheds with medium-textured soils. This information, though based on a relatively short period of record, is immediately useful in designing stock ponds and other upstream reservoirs. (SWC 1-d1)

In Oklahoma, investigations of sediment transport are being carried out in a study reach of the Washita River main stem to provide an understanding of the effects of watershed treatment on sediment yield and transport in the main stems of large rivers. At the upper end of the study reach, which has a drainage area of 3656 square miles, the total sediment transport was 360 tons per square mile. At the lower end of the study reach, 78 miles downstream, where the drainage area is 4784 square miles, the total sediment transport was 480 tons per square mile.

Thus, the sediment contribution of the intervening drainage area is being bracketed, though as yet the data are insufficient to define the reasons for the increased sediment load. (SWC 1-e1)

At Riesel, Texas, studies in the Blacklands soils are showing that sediment yield from conservation-treated watersheds in the 100- to 200-acre size range is only one-eighth of that from nonconservation farmed watersheds. Ninety-five percent of the sediment from the nonconservation area and 90 percent of that from the conservation area occurred for flows above 10 cubic feet per second; but only 70 percent of the runoff occurred above this rate. (SWC 1-e1)

After examination of several proposed experimental areas during the past year, the Calleguas Creek Watershed near Moorpark, was selected for initiating studies of sediment yields and other sedimentation problems in southern California, from the Lompoc headquarters. This general area is one of severe and persistent problems in erosion, sediment yield, and stabilization of stream channels. These data will be used extensively by all agencies that have responsibilities involving construction of reservoirs or research in sedimentation. Extensive surveys and historical information have been collected in the Calleguas Watershed over the past 30 years by the Soil Conservation Service, the local Soil Conservation District, California Technological Institute and others concerned with the sedimentation problems in this area. The SCS will cooperate in assembling available information for analyses and in planning a program of continuing field studies. (SWC 1-g1)

B. Rates and Processes of Reservoir Silting

A compendium of all reservoir sedimentation surveys made in the United States through 1960 was compiled by the Sedimentation Laboratory at Oxford, Mississippi, under the auspices of the Subcommittee on Sedimentation, Interagency Committee on Water Resources, and prepared for publication as a USDA Bulletin. This compilation includes sedimentation survey results from 1,069 reservoirs, ranging in size from stock ponds to large reservoirs on the Colorado and Missouri Rivers, with an aggregate original storage capacity of almost 97 million acre-feet. The average annual sediment accumulation in these reservoirs is about 268,000 acre-feet, with average annual capacity losses ranging from 0.0002 to 100 percent.

Significant progress has been made at the Sedimentation Laboratory, Oxford, Mississippi, in the development of a dual-gamma probe for use in measuring the density (volume-weight) of sediment in reservoirs. The dual-probe permits accurate incremental readings, beginning 1 inch from the sediment surface, and thus overcomes the critical limitation of the single-probe device for accurate measurements in the upper 9 inches of deposits. Further development and testing, particularly in regard to ruggedness and physical makeup, are needed before the dual-probe will be

ready for general field use. The adaptation of radioisotope techniques for the measurement of reservoir sediment density has greatly improved the accuracies of values obtained and is considered a major advance in greatly increasing the utility of reservoir sedimentation survey results as indices of sediment yield. (SWC 1-bE2)

The stage-area curve method for determining reservoir capacity is more direct and accurate than any other method available, according to findings at Lincoln, Nebraska. These findings were based upon very detailed studies of four small reservoirs in South Dakota and experience elsewhere. Volumes of deposited sediment can readily be estimated by use of differences in successive stage-area curves. Surveys of the spillway contour and next lower contour, in addition to cross sections (ranges), aid materially in developing good contour maps. Parallel ranges at right angles to a single monumented base line not only saved time and cost of establishing and monumenting ranges, but produced more accurate reservoir capacity estimates for small reservoirs than skewed, individually monumented ranges. (SWC 1-d1)

Two ponds near Newell, South Dakota, one very irregular and the other uniform in topography, were partially emptied with a pump through a Sparling flowmeter. Stages of the ponds were observed during the pumping tests. The volumes of water indicated by the flowmeter were 5 to 9 percent less than capacities indicated by stage-capacity curves based on pond surveys made two years ago. Therefore, new and more detailed instrument surveys were made of these ponds. Examination of these new survey data indicates that the pumped water volumes check very closely with the new stage-capacity curves, thus verifying the techniques used extensively by both operations and research personnel. (SWC 1-d1)

Sediment deposits were measured in four stock ponds, ranging in age from 4 to 22 years, on the Walnut Gulch Experimental Watershed at Tombstone, Arizona. The average annual sediment accumulation ranged between 0.20 and 0.70 acre-foot per square mile of drainage area. Several sediment samples were collected from the measured inflow of summer storm runoff into one of these ponds. These data, when corrected for deposition above the measuring weir, indicated an average sediment inflow of approximately 1 percent by weight of water entering the pond. This value, coupled with a rough estimate of total water flow into the pond in its 22 year life resulted in an estimate of total sediment inflow which checks rather closely with the accumulated deposit measured. These findings are useful in designing sediment pool storage in an area where little such information is available. (SWC 1-g3)

C. Mechanics of Sediment Entrainment, Transportation, and Deposition

Sediment transport, water discharge, channel shape, bed and bank configuration, and channel roughness are intimately related. Some of the incongruities of these relationships are well illustrated by some

observations on variations in channel roughness on Laboratory Creek, Oxford, Mississippi, and Barber Creek at Watkinsville, Georgia. On Laboratory Creek, roughness values decreased with increasing stage, in accordance with general concepts, but on Barber Creek, roughness values increased with increasing stage until near bank-full and then decreased slightly or remained constant. Manning's "n" values varied from 0.05 to 0.019 on Laboratory Creek where the mean bed-material size was 0.36 mm. The "n" values varied from 0.019 to 0.045 on Barber Creek and in this case the mean bed-material size was about 1.0 mm. Investigations to determine the causes of differences in roughness coefficients of these channels are continuing. Inasmuch as "n" values have been considered to be a single-valued function for a stream channel, the implications of these preliminary findings are quite important in the whole field of open channel flow. (SWC 1-bE3)

Efforts continued at the Sedimentation Laboratory, Oxford, Mississippi, to clarify the relation between sediment load measured by the conventional suspended sediment sampler and that moving along, unmeasured, below the sampler's intake nozzle. For the Pigeon Roost Creek streams, this unmeasured portion amounts to about 22 percent of the total sediment load in movement. A small sheet-pile drop for measurement of total transport was installed in 1962, and installation of a concrete Parshall flume and two additional sheet-pile drops is planned for 1963. An improved total-transport measuring device that permits time-integrated sampling was installed in the 100 foot laboratory flume during 1962. This device probably provides the best measurements in any present-day flume experiments. (SWC 1-bE1)

In a study at the Sedimentation Laboratory it was found that the concentration of sediment collected with conventional samplers varied several hundred percent, depending upon the nozzle location in relation to moving dune fronts. These findings help to explain the inconsistencies sometimes found in sampling sediment load of streams and further emphasize the need for improved techniques and equipment for determining sediment movement. (SWC 1-bE1)

D. Stream Channel Morphology and Means and Measures for Channel Stabilization.

The March 12, 1962, flood on the Pequest River in New Jersey, where channel improvement measures had been previously established by the Soil Conservation Service, provided an excellent opportunity for comparing channel performance to channel design. The peak flow for the 1962 flood was equal to that for the design flood. The hydraulic qualities of the channel—particularly velocity, boundary shear stress, slope of the energy gradient, and retardance coefficient—were found to be in close agreement thus providing confidence in some of the design techniques developed from past research. (SWC 1-bE3)

At East Aurora, New York, a study was made of how minimum energy losses occur in open channel bends in relation to the character of the bend by reviewing hydraulic investigations of others and applying results of the study to conditions of the Buffalo River. It is commonly known that the channel cross section at a bend deepens and widens with time, the deepening being more pronounced than the widening. Since deepening does not occur on the Buffalo River where the stream bottom consists of a smooth shale bed, a formula has been developed to determine the maximum width of channel to be attained in the bend, based on the width of the channel at the entrance to the bend and on radius of curvature of the outer bank of the bend. Subsequent observations to verify the hypothesis on the formula will be made and if the formula is valid a useful tool will have been developed for the planning of stream channel stabilization work. (SWC 1-a1)

Laboratory studies of the stability of stream channel banks dug in sandy soils of Florida have shown that the angle of repose of the materials is 30 degrees when saturated, or underwater, and 9 degrees when above water. The fineness of the sands (0.13 mm. median diameter) and seepage inflow are both conducive to bank caving. The implication to date is that channels dug to a trapezoidal shape under these circumstances will evolve to an elliptical shape. Prediction of the final shape of the channel may make possible some savings in the costs of excavation. (SWC 1-b4)

Whether structural or vegetative methods should be used for bank stabilization is sometimes quite apparent; however, recent information indicates that vegetation can often be used in lieu of more expensive structural measures such as riprap. Through analysis of data collected by others, it was found at the Sedimentation Laboratory, Oxford, Mississippi, that a good stand of long green vegetative cover was equivalent to a riprap size of 6.5 inches under an allowable shear stress of 3.2 lbs. per square foot. (SWC 1-bE1)

Studies in a rigid-bed model have shown that shear stresses in channel bends have a maximum value at the lower outside of the bend that is about double the average shear stress at entrance to the bend; yet, field experience has shown that riprap protection designed to withstand this direct shear force has been destroyed. This suggests that other forces, actually equivalent to several times the theoretical direct shear, are acting on the riprap. A laboratory study has been initiated at the Sedimentation Laboratory, Oxford, Mississippi, whereby all forces acting on the individual particles, including the "plucking" action, will be investigated. (SWC 1-bE3)

The results of the first phase of an intensive study of the characteristics of cohesive materials that make them resistant or nonresistant to the forces of flowing water are becoming available at the Sedimentation Laboratory. It has been found that, in addition to temperature, the type, amount, and orientation of the clay minerals and the density and

antecedent moisture content of materials are related to the stability of cohesive materials under fluid action. These basic studies clearly indicate that an understanding of the physical characteristics of periphery materials in channels is as important as an understanding of the acting hydraulic forces. (SWC 1-bE3)

Carbon-14 dating apparatus at the Sedimentation Laboratory was utilized continually during 1962. Buried samples of organic material from several locations were analyzed to determine age. The relation of age to overburden or valley fill is beginning to yield information on probable rates of valley aggradation and channel morphologic development. For example, samples from the Washita River basin in Oklahoma indicate an average valley aggradation rate that is several hundred percent higher than previous estimates which were based upon the usual geologic criteria. If examination of the materials in other river valleys results in similar findings, a complete re-examination of present day concepts concerning the length of time required for a river channel system to change its character will be in order. (SWC 1-bE3)

Field studies made on 38 gully-control structures and 6 debris dams in southwestern Wisconsin showed that the average slope of the deposition profile upstream from the structure could be predicted from certain features of the original channel and of the structure. These significant variables are the original channel slope, the width of the channel at the structure, and the height of the dam above the channel bottom. In the design of a series of structures for gully control, location and spacing depend on the stable channel gradient between them. The use of findings from this research program will result in greater economy in construction and more effective operation. This prediction technique applies only to the region it represents, additional research being required to adapt the techniques for application elsewhere. (SWC 1-c2)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Minshall, N. E. 1962. North Central Watershed Research Center. Mo. Agr. Expt. Sta. Brochure.
Soil and Water Conservation Research Division Staff. Sedimentation research from field to laboratory to control. USDA Picture Story 137: 4 pp.
McCalmont, Virginia, ARS Information Division. 1963. USDA Sedimentation Laboratory. U.S. Dept. Agr. Misc. Pub. No. 918: 16 pp.

Sediment Sources and Yields from Agricultural Watersheds

Diseker, Ellis G., and Richardson, E. C. 1962. Erosion rates and control methods on highway cuts. Amer. Soc. Agr. Engin. Trans. 5(2): 153-155.
Dragoun, Frank J. 1962. Rainfall energy as related to sediment yield. Jour. Geophys. Res. 67: 1495-1501.
Miller, Carl R. 1962. Soil erosion. Cotton Gin and Oil Mill Press 63(9): 2 pp.
Miller, Carl R., Woodburn, Russell, and Turner, Herschel R. 1962. Upland gully sediment production. Internatl. Assoc. Sci. Hydrol. Symp. on Land Erosion 59: 83-104.
McHenry, J. Roger, and McDowell, Leslie L. 1962. The use of radioactive tracers in sedimentation research. Jour. Geophys. Res. 67: 1465-1471.

Rates and Processes of Reservoir Silting

Heinemann, Herman G. 1962. Volume-weight of reservoir sediment. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-5): 181-197.
Heinemann, Herman G. 1962. Using the gamma probe to determine the volume-weight of reservoir sediment. Symp. on Land Erosion Proc., Bari, Italy 1962: 410-423.
McHenry, J. Roger. 1962 Determination of densities of reservoir sediments in situ with a gamma probe. U.S. Dept. Agr. ARS 41-53: 10 pp.
McHenry, J. Roger. 1962. Determination of sediment density by gamma attenuation. U.S. Dept. Agr. ARS 41-61: 16 pp.

Mechanics of Sediment Entrainment, Transportation and Deposition

Brakensiek, D. L. 1962. Discussion: "A method for measuring the effects of environmental factors on channel properties," by M. A. Melton. Amer. Geophys. Union Trans. 67: 1491-1492.
Coleman, Neil L. 1962. The behavior of a DH-48 hand sampler among sand dunes. Ole Miss Engin. 2(4): 6-8 pp.
Coleman, Neil L. 1962. Observations of resistance coefficients in a natural channel. Internatl. Assoc. Sci. Hydrol. Symp. on Land Erosion 59: 336-352.
Long, Fred W., and Bowie, Andrew J. 1962. Sediment concentrations of three selected rises on Pigeon Roost Creek. Assoc. South. Agr. Workers, Inc. Proc. 59th Ann. Conv. p. 46.

Miller, Carl R. 1962. Recent developments in sedimentation research and installations. U.S. Pacific Sowest. Inter-Agency Comt. Minutes Mtg. 62: 28-37.

Stein, Richard A. 1962. Discussion: "Dual channel stream monitor: by S. S. Karaki, E. E. Gray, and J. Collins, American Society of Civil Engineers Proceedings Paper #2976, November 1961. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-3): 217-221.

Stream Channel Morphology and Means and Measures for Stabilization

Ippen, Arthur T., and Drinker, Philip A. 1962. Boundary shear stresses in curved trapezoidal channels. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-5): 143-17.

Ippen, Arthur T., Drinker, Philip A., Jobin, W. R., and Shemdin, O. H. 1962. Stream dynamics and boundary shear distributions for curved trapezoidal channels. Mass. Inst. Technol. Tech. Rpt. 47: 81 pp.

Miller, Carl R. 1962. Discussion: "The process of channel degradation," by Dr. E. R. Tinney. Jour. Geophys. Res. 67: 1481-1483.

Miller, Carl R., and Borland, Whitney M. 1963. Stabilization of Fivemile and Muddy Creeks. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 89(HY-1): 67-98.

Woolhiser, David A., and Miller, Carl R. 1963. Case histories of gully control structures in southwestern Wisconsin. U.S. Dept. Agr. ARS 41-60: 28 pp.

AREA 2: HYDROLOGY AND WATER RESOURCES RELATED TO AGRICULTURAL WATERSHEDS

Problem. The Department's Conservation Needs Inventory indicates there are nearly 12,000 watersheds in the country of a size needing protection or suitable for development under the Watershed Protection and Flood Prevention Act, the Small Reclamation Projects Act, and similar programs. About 8,300 of these watersheds need project action for development of flood prevention systems, water supply works, public recreation areas, and irrigation and drainage enterprises.

Efficient planning and execution of programs for protection and development of upstream watersheds require an understanding of the basic factors governing the hydrology of agricultural watersheds and their associated aquifers.

Research-derived procedures for estimating floodflows, water yields, hydrograph shapes, base flow, and ground water accretions in relation to the use and treatment of watershed lands in the various geo-climatic regions of the country are an urgent need. Research on relations between improvement works in upstream tributaries and floodflows and water yields downstream along the principal tributaries and the main stems of major rivers is also a conspicuous need.

This research provides an insight into the operation of the hydrologic cycle in agricultural watersheds. From it are derived prediction equations and criteria for the more efficient design of watershed programs and utilization of water resources.

USDA PROGRAM

The Division has a continuing long-term program involving hydrologists, geologists, meteorologists, soil scientists, range scientists, and statisticians in both basic and applied research on the hydrology of agricultural watersheds. The studies are aimed primarily toward providing information useful in connection with the protection and development of resources in upstream watersheds. The work is in progress in the 19 states of Arizona, California, Florida, Idaho, Iowa, Maryland, Mississippi, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, South Dakota, Texas, Utah, Vermont, Virginia, West Virginia, and Wisconsin. All work is cooperative with the respective State Agricultural Experiment Stations. Other cooperators in these studies include State of California, Department of Water Resources, Santa Barbara County Water Agency, Central and Southern Florida Flood Control District; Geology Department, Oklahoma State University, Vermont State Water Conservation Board, Potomac Valley

Soil Conservation District; Wisconsin Valley Improvement Association, and a large number of individual farmers and ranches throughout the United States.

The research efforts in all the states are aimed at a comprehensive understanding of the hydrologic cycle as it applies to the development and protection of upstream watersheds. However, because of the inherent differences in problems, special emphasis is given to water yield aspects in the West and to the flood aspects in the humid East.

The scientific effort directed to this area of research totals 49.8 professional man-years. Of this number, 8.6 are devoted to studies of precipitation patterns; 5.8 to soil moisture accretion and depletion; 6.1 to ground water accretion, movement and basin recharge; 7.5 to aquifer-streamflow relationships; 10.4 to water yield and water supply and quality; and 11.4 to floodflows and storm runoff.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Precipitation Patterns

Several studies have been made at Danville, Vermont, to explain why the higher elevations of the 42 square mile Sleepers River Watershed receive significantly greater amounts of precipitation than the lower elevations. A meteorological analysis of storm movement and direction in relation to shape and orientation of the watershed indicated that the orographic effect was not directly significant. Thus, in order to extend the findings of precipitation and rainfall-runoff relation research at Danville to other areas, it is necessary to find some parameter other than elevation to serve as a "common denominator." In a different approach involving classification of storms by types, it was found that storms classified as "cold air mass" produced 140 percent more precipitation at the higher watershed elevations while those classified as "cold front," "warm air mass," and "warm front" produced only 40 percent more precipitation at the higher elevations. It is hoped that this classification, further refined, will lead to a method of estimating the volumes of rainfall to be expected at different elevations. (SWC 2-a1)

Studies of storm rainfall at Coshocton, Ohio, showed a relation between the density of a raingage network and the average error in measurement of rainfall on a watershed. The results are directly useful as a guide in selecting the density of a raingage network required for results within a preselected error limit. Savings in cost of gages in excess of those necessary to provide results of required accuracy in the Coshocton area are thus made possible. (SWC 2-c1)

An analysis of sixteen years of data from five raingages at Hastings, Nebraska, indicated small but statistically significant, differences in catch of a recorder, a standard, a standard on a 6-foot post, and standard raingages with Alter and Nipher shields. Although statistically significant differences in daily catch were found, differences were so small that they probably have no practical importance from a climatic or rainfall-runoff-relation standpoint, inasmuch as the inherent error in other measurements is quite large. The mass of recording raingage data being obtained at the Central Great Plains Experimental Watershed can, therefor, be used with confidence in analyzing the runoff and other data being obtained. Furthermore, extension of research findings to other areas when only standard-gage data are available can also be made with confidence. (SWC 2-d1)

Convective-type thunderstorms typical of semiarid areas were the most frequent precipitation events in the past year over the 48 square mile Lowry Draw watershed at Sonora, Texas. The resulting rainfall pattern was highly erratic, with appreciable rainfall amounts within the small storm cells and little rain between the cells. (SWC 2-e1)

The variability of annual rainfall amounts in relatively short distances was illustrated by records from the network of 182 recording raingages, spaced approximately on a 3- by 3-mile grid, over the 1,128 square mile Anadarko-Alex study reach of the Washita River Basin. Total rainfall in 1962 ranged from 37.5 to 22.3 inches in comparison to the normal expected variation of about 3 inches from east to west in the study area. Obviously, one years' record is not sufficient basis for establishing a pattern of normal precipitation but these data do emphasize the critical importance of the rainfall factor in studies of streamflow in relation to land use and treatment practices on tributary watersheds. (SWC 2-e1)

At Bushland, Texas, studies of radar echoes of convective storm cells over the Texas High Plains showed that most cells had a life of only 12 to 18 minutes, and that the median duration was 36 to 48 minutes. Most of the cells did not move, but the median distance travelled by all cells was 0 to 5 miles with a median speed of 0 to 5 miles per hour. The storm cells occurring most frequently were 10 to 15 square miles in area, with the median size being from 25 to 30 square miles. (SWC 2-e1)

In a study of precipitation characteristics in the Northwest, it was found that annual precipitation on the 93 square mile Reynolds Creek Experimental Watershed, southwest of Boise, Idaho, ranged between 4 and 30 inches in 1962. About 15 to 20 percent of this precipitation fell as convective rainfall, principally from February to October, with most frequent occurrence during May. There appear to be orographic effects upon winter-type storms in this area, but precipitation from convective storms seems to be unrelated to topographic features. (SWC 2-f2)

On the Reynolds Creek Experimental Watershed in southwestern Idaho, snow density varies widely, not only from time to time during the winter, but also from place to place even on a small area. Observations on one 90-acre study area in sagebrush showed that 80 percent of the snow depth was contained on about 83 percent of the area and that about the same relationships pertained between snow water content and depth. (SWC 2-f3)

A horizontal-search radar unit was installed on Walnut Gulch Watershed at Tombstone, Arizona, as an aid in closing isohyetal lines for storms lying partially outside of the watershed and its intense recording raingage network. The Unit will also be very useful for better interpolation between gages within the watershed. (SWC 2-g1)

The intensive recording raingage networks covering the 58 square mile Walnut Gulch Watershed at Tombstone, Arizona, and the 67 square mile Alamogordo Creek Experimental Watershed near Santa Rosa, New Mexico, continued to add to the mass of data needed for characterization and prediction of the extremely variable and sometimes very high intensity summer runoff-producing storms in the Southwest. Predictions of storm runoff as it relates to floods, yields of usable water, and sediment carried into streams from semiarid rangeland watersheds depend, first of all, upon adequate prediction of the runoff-producing rainfall. (SWC 2-g1)

At all the research locations in the West, where intensive networks of raingages have been established, it is becoming apparent that the area size and volume of thunderstorm rainfall events is remarkably different than has been believed. These research findings, when further refined, will have a substantial bearing on design criteria for upstream structures. (SWC 2-g1)

An exploratory study on rainfall vectors was initiated at Lompoc, California. Records of a vecto-pluviometer, installed on a steep hillside, showed the mean inclination of the rainfall was 43 degrees with respect to the horizontal. The angle of inclination from the horizontal generally increased with the intensity of the rainfall, but the maximum measured was 60 degrees. The direction of rainfall at this site was generally from the south early in the calendar year, and moved clockwise into the northwest quadrant by the end of the winter rainfall season. (SWC 2-g1)

B. Soil Moisture Accretion and Depletion

At Oxford, Mississippi, a soil moisture accounting procedure for unsaturated flow was developed to determine antecedent soil moisture conditions, a first requirement for predicting runoff and associated sediment yield. Computations of direct runoff from storm rainfall for three small watersheds with decidedly different cover conditions and runoff characteristics gave satisfactory results. The rainfall-runoff

prediction model, readily adaptable for digital computer use, requires only easily available climatic data and appears suitable for general application. (SWC 2-b4)

Analysis of data for the prediction of extreme runoff events in the Pigeon Roost Creek Watershed, in northern Mississippi, was completed and emergency procedures prepared for obtaining field observation during the greatest events. The 10-, 25-, 50-, and 100-year flood events were estimated at 11,300; 14,000; 16,100; and 19,000 c.f.s. for the 117 square mile watershed. In February 1963, a peak discharge of 12,200 c.f.s. resulted from a 3.31-inch rainfall. Thus, a 15-year streamflow event occurred from a 2- to 3-year frequency rainfall because of high soil moisture that produced optimum runoff conditions. Such occurrences emphasize the importance of the soil moisture index in forecasting streamflow. (SWC 2-b4)

Previous studies at Fort Lauderdale, to find out which formula gave the most consistent results in computing monthly pan evaporation for south Florida showed that the Weather Bureau Method ranked highest and the Thornthwaite Method lowest of nine methods. In a comparison of measured versus computed potential evapotranspiration from a grass sod, the simpler formulas that require only latitude and temperature varied from 73 percent in the Thornthwaite to 87 percent in the Modified Blaney-Criddle Method in accounting for variations. The more complex methods including the Penman, Weather Bureau, and Fractional Evaporation-Equivalent gave the most reliable results. These latter methods accounted for approximately 90 percent of the variations. In all cases, evapotranspiration was predicted with greater accuracy than was pan evaporation. (SWC 2-b1)

Water budget studies at Coshocton, Ohio, showed that in a growing season of subnormal rainfall, nearly 8 inches of moisture were extracted from a 72-inch soil profile by a high-yield crop of wheat. This depletion was about 3 inches more than that on an area of average crop yield. Extensive investigations were initiated during the year to provide additional essential information on the variability of soil moisture on a watershed basis so that flood flows and water yields from upstream watersheds can be predicted more accurately. (SWC 2-c3)

Studies to better define the effect of land use on moisture dissipation from the soil are being made on the Texas Blackland Prairies at Riesel, Texas. Work done in 1962 indicates that a perched ground water table 7 feet or more below the ground surface is not a major factor influencing soil moisture dissipation rates. This finding permits placing increased confidence in runoff prediction schemes developed at this location. (SWC 2-e2)

Studies conducted at Lompoc, California, showed that coastal climatic conditions in that vicinity substantially influence evapotranspiration. These studies also indicated that none of the climatic indices and empirical formulae commonly used for predicting evapotranspiration provided satisfactory results under these coastal influences. Indications of the study also were that under certain inland conditions, represented in the Central Valley of California near Bakersfield, usual estimating procedures were adversely affected by man-made haze (smog). Estimates of watershed evapotranspiration are essential to prediction of their net yields of usable water. A low cost, portable, in-situ-type, weighing lysimeter has therefore been developed at Lompoc. This equipment is adaptable for studies of evapotranspiration of range vegetation, including grasses, forbs and half-shrubs, and can be moved about to study and evaluate the various coastal and topographical conditions. The locality of Lompoc is especially suited for these studies of evapotranspiration because of the unusual climatic gradient from the coast to dry, hill areas a few miles inland. (SWC 2-g3)

C. Ground Water Accretion, Movement and Basin Recharge

A study of ground water accretion and depletion has been initiated at Danville, Vermont, with the installation of 73 piezometers to depths of 3, 5, and 7 feet, and 6 ground water level recorders on two small watersheds. Sixty-eight temporary V-notch weirs were also installed for the same purpose on first order and larger streams. The study will provide an excellent basis for associating ground water storage and depletion rates—important factors in water yield— with watershed characteristics. (SWC 2-a3)

Continued hydrogeologic investigations in Pigeon Roost Creek Watershed, Mississippi, resulted in development of stratigraphic, structural, and ground water maps of the basin. New test wells substantiated the presence of a fault just beyond the southeastern boundary of the watershed and aided in delineating the ground water flow pattern. The principal aquifer, the Meridian Formation, was observed to be 180-200 feet thick and to dip to the south and west. Its porosity was evaluated at 30 percent and its permeability at 0.1763 cm/sec. Annual ground water outflow from the watershed through the Meridian was computed to be approximately 3 inches, and stable piezometric gradients observed for 2 years lead to the conclusion that such losses are steady. Ground water storage in the Meridian under the watershed was calculated to be about 4 million acre-feet, but this entire volume would not be yielded to wells because of capillary retention. This study points up the necessity for making careful geologic studies on any watershed being developed for water supply, as well as providing a guide for making such studies. (SWC 2-b4)

At Coshocton, Ohio, percolation to ground water was less on an area of high-yield crops, and slower in starting, than on an area of average crop yield. By February following the crop season, percolation to

ground water from the high-yield area totaled 0.10 inch whereas that from the average-yield area totaled 1.91 inches. Decreases in aquifer recharge in this area result in decreases in streamflow. In water-supply design problems, evaluation of all factors affecting aquifer recharge in a significant manner, including land use and management practices, becomes very important.

Instrumentation on the Lowry Draw watershed in the vicinity of Sonora, Texas, provided information on the effects of floodwater-retarding reservoirs upon ground water recharge in the Edwards Plateau. Streamflow was low for the year and nearly all inflow to the detention reservoirs entered the subsurface caverns and channels through solution openings in the reservoir bottoms. Ground water wells adjacent to a reservoir showed very marked rises as a result of entry of water into the subterranean chambers. but wells a short distance away showed no rise. (SWC 2-e4)

Five land and water use problems related to geohydrology have been recognized and some of their causes and interrelations defined for the western two-thirds of the Anadarko-Alex study reach of the Washita River Basin, in the vicinity of Chickasha, Oklahoma. The problems are: (1) shallow water tables, (2) highly mineralized ground and surface water, (3) salt cedar growth, (4) saline-alkaline surface and near-surface deposits, and (5) evapotranspiration losses of ground water. Recognition of the problems is the first step towards developing an understanding of the relation of upstream watershed treatment to the ground water hydrology of the main stem of the Washita River. (SWC 2-e4)

At Boise, Idaho, a study of the hydrologic properties of basalt aquifers showed that the permeability and transmissibility of the Reynolds Creek Experimental Watershed basalts are much lower than those of the basalts of the Central Snake River Plains. The difference is primarily due to presence of alteration clays within the interstices of Reynolds Creek basalts. Basic knowledge of the characteristics of geologic materials of research watersheds is required before research findings can be extended to other areas. (SWC 2-e4)

A drilling exploration program was initiated and is continuing at Tombstone, Arizona, to locate the regional water table, and to geometrically define and mechanically characterize aquifers underlying the Walnut Gulch Experimental Watershed. This is an essential part of the job of evaluating the net water yield characteristics of the watershed, and determining how and to what extent the yields of water for downstream use from this and other arid rangeland watersheds may be affected by changes in their management. (SWC 2-g3)

D. Aquifer-streamflow Relations

At Ft. Lauderdale, Florida, in connection with a study of water table gradients normal to stream channels, a method was developed to use a single recorder station to estimate mean ground water depth for intervals between readings of a series of wells along an extended line. The significance of this development is that where gradients are determined from nonrecording wells, peaks caused by rainfall between periodic observations can be estimated for each well in the series. (SWC 2-e4)

Studies of interflow were continued at Coshocton, Ohio, but only a few storms producing interflow have occurred since instrumentation for its measurement was established. These studies are primarily intended to establish information on the contribution of subsurface flow to hydrographs of storm runoff and to assist in understanding the effects upon floodflows and water yields of land use and treatment practices on small field-size watersheds. (SWC 2-c5)

In a study of the water balance in the irrigated portion of Reynolds Creek Experimental Watershed in southwestern Idaho, 2.0 of the 4.1 acre-feet per acre of water diverted from Reynolds Creek for irrigation was retained in the irrigated area. The remaining 2.1 acre-feet per acre returned to the stream as either seepage or runoff. Return flow of 1.3 acre-feet occurred after diversions stopped. Computation of consumptive use by the Blaney-Criddle formula, based upon temperature data and daylight hours, indicated consumptive use to be 2.06 acre-feet per acre, which agrees quite closely with the measured amount. (SWC 2-f1)

The very large stream channel transmission losses measured on the Walnut Gulch Watershed at Tombstone, Arizona, have been previously reported. Limited opportunities for additional determinations of transmission losses in the past season served to verify earlier estimates of the relationship of channel abstraction rates to the magnitude of flows. Two more flow-measuring structures were completed and another started in the tandem system of flow-measuring stations, thus increasing the opportunities for measuring channel losses in reaches of varied dimensions, flows, and geologic materials. (SWC 2-g3)

Studies of ground water levels in wells along the channels of Walnut Gulch Watershed at Tombstone, Arizona, indicated that some portion of the water percolating into the sand and gravel channel materials is being held in local aquifers where possibilities exist for exploitation for strictly local use. Presently this water is largely consumed by riparian trees and shrubs. Studies are being continued and expanded to evaluate net losses and salvage possibilities associated with the very high channel transmission losses of storm runoff flows being measured on this watershed. (SWC 2-g3)

E. Water Yield and Water Supply and Quality

At Moorefield, West Virginia, annual runoff from four pastured watersheds, 6.3 to 9.7 acres in size and on shale soil, ranged from 3.6 to 5.5 inches and averaged about 13.7 percent of the total precipitation for the year. Data from these watersheds are now being analyzed to determine representativeness of the period of record. When an adequate calibration has been established, two of the watersheds will be "chiseled" to determine the effects upon runoff resulting from breaking the shale subsoils. The practice of chiseling is one that many are hopeful will be effective in reducing floods and increasing low flows. (SWC 2-a2)

The problem of preventing ice in the stilling wells of gaging stations has largely been solved in the past by the installation of an electric heater. This solution has been satisfactory where electricity is readily available, though the operational costs are high. A solution for remote locations has been found at Danville, Vermont, by adapting bottled-gas livestock-tank heaters. These heaters have performed very satisfactorily and economically after working out several draft and exhaust problems. Consideration is now being given to replacing the high cost electric heaters at all locations with the low cost bottled-gas heaters.

The 893-acre Brush Creek watershed in the Blue Ridge Mountain land resource area, with annual streamflow averaging about 53 percent of precipitation, continues to show the highest water yield of the 10 complex watersheds under observations from headquarters at Blacksburg, Virginia. Streamflow from the 3,054-acre Thorn Creek watershed in the Appalachian Valleys and Ridges land resource area has averaged about 15 percent of precipitation the past 5 years and has the lowest water yield of the 10 watersheds. For the other 8 watersheds average annual streamflow varies from about 22 to 37 percent of annual precipitation. Data from these watersheds, as well as others in Virginia and neighboring states, will provide much needed information on water yields and flood flows from upstream areas. (SWC 2-a2)

At Holly Springs, Mississippi, runoff from a pasture watershed and from a comparable cultivated watershed, each several acres in size, has been approximately equal each year for the 4-year period 1959-62. On the other hand, runoff from fraction-acre cultivated plots has exceeded runoff from comparable pasture plots by about 40 percent. Since cultural conditions were the same on plots and watersheds, these results demonstrate the necessity of adequate information on geomorphic characteristics of unit-source watersheds in addition to information on infiltration for predicting their hydrologic performance. (SWC 2-b1)

The Watershed Hydrology Research Center at Columbia, Missouri, is studying streamflow data from the Claypan area of the North Central States. Analysis of seasonal and annual precipitation and runoff values for 82

drainage areas of 25 acres to 8220 square miles in this region showed that the quantities of streamflow per square mile were not significantly affected by size of watershed. For example, if the 6 months water yield of a once in 25-year recurrence for a 10 quare mile watershed is 3 inches, the same amount of runoff in inches is expected to be available from a 50-square-mile watershed, these procedures for predicting water yield in the claypan area are relatively simple. This finding is significantly different from that for some regions where sizeable gains or losses in streamflow occur with increased area. (SWC 2-c4)

The Cooperative Water Yield Procedures Study at Lincoln, Nebraska, originally scheduled to extend over a 5-year period, was completed during the year and a report submitted for editing and publication. This cooperative study by the Agricultural Research Service, Soil Conservation Service, and the Bureau of Reclamation sought a method, through analysis of available information, for evaluating the effects of upstream land and watershed treatment upon downstream water yield in the water-deficient areas of the West. Though provisional and subject to revision as more data become available, the derived method will be helpful for guidance in the development of programs and practices for conserving and using water yielded by streamflow in rivers of the area. (SWC 2-d1)

Studies to determine the effects of degree of use of rangeland on water yield were installed on the Cottonwood Field Range Experiment Station, near Cottonwood, South Dakota, in cooperation with the South Dakota Agricultural Experiment Station. These studies were established on 12 watersheds, each about 2 acres in size, and on pastures which had been lightly, moderately, and heavily grazed for the past 20 years. It is believed that this research is the first of its kind to be undertaken on areas with such a long history of grazing use. The study will provide information on a question that has been extremely controversial. (SWC 2-d1)

The late spring and early summer at Newell, South Dakota, was one of the wettest on record. Runoff from watersheds of fine-textured soils was about four times that from watersheds with medium-textured soils. For example, runoff from one of the former was 27 percent of the 22.6 inches of precipitation occurring in 1962, whereas maximum runoff from a watershed with medium-textured soil was only 6 percent of annual precipitation. The hydrologic information from these watersheds is immediately useful in the design of water use and control structures. (SWC 2-d1)

At Stillwater, Oklahoma, a 17-acre watershed in native grass rangeland yielded 6.0 inches of runoff for an annual rainfall of 27.5 inches. This is a higher percentage runoff than in past years and was attributed to the overgrazed condition of the watershed. In 1958, a year of similar rainfall but of good range condition, 28.4 inches of rainfall produced 4.1 inches of runoff. An adjacent watershed of more constant

range condition over this period had about the same amount of runoff for the two years. (SWC 2-e4)

The three ponds which intercept 20 percent of the 206-acre native grass rangeland watershed under observation at Stillwater, Oklahoma, retained only 3.6 percent of the total runoff from the entire watershed. When runoff occurred the ponds generally overflowed; otherwise, they would have retained 20 percent of the total runoff. Thus, even in dry years such as 1962 when the effects of ponds in reducing downstream runoff would be proportionally the largest, the effect was relatively small. These results are of vital interest in the West where many people believe that farm ponds greatly reduce downstream water yield. (SWC 2-e4)

F. Floodflows and Storm Runoff

Lack of a satisfactory basis for expressing the hydraulic characteristics of a watershed is a major difficulty in predicting the shapes of runoff hydrographs. Techniques were developed at the Hydrograph Laboratory, Beltsville, Maryland, for rapidly determining the storage-flow relationship for a watershed from flow recessions after the cessation of rainfall, and subsequently, for expressing the hydrograph in terms of the volume and duration of rainfall excess, and the watershed storage coefficient. The watershed storage coefficient can also be used for routing the hydrograph to a downstream point, thus providing the proper attenuation not achieved by the usual practice of lagging inflow hydrographs downstream to a point where stream routing is started. (SWC 2-aD1)

An iterative process, for flood routing through the simultaneous solution of the equation of motion and the equation of continuity of mass, is being developed in the U.S. Hydrograph Laboratory at Beltsville, Maryland, and programmed for digital computers. The digital computer will make it possible to apply much of the knowledge of hydraulics which has hitherto been impossible because of the great mass of computations involved. Initial solutions for reaches in uniform channels appear very promising and analyses will continue for final verification using research data from the experimental watershed at Hastings, Nebraska. A technique for computing the profile of flood wave passing through a stream reach, to determine the hydrograph and associated inundation, is the primary objective of the study. (SWC 2-aD1)

In studying the effects of snow cover on floods, it was found at Danville, Vermont, that only a very small percentage of the watershed was contributing to the volume of runoff when the snow first began to melt. In this situation, the usually high stages of the streams and the ice conditions in the streams during the spring runoff season directly affect the shape of the hydrograph. When the snow cover is not melting and rainfall occurs, the time lag between intense rainfall and the peak of the hydrograph is apparently dependent on the depth and permeability

of the snow cover as well as on the usual watershed factors. As the snow melt or rainfall continues, the runoff-contributing area gradually increases until finally the entire watershed is contributing and then the usual watershed characteristics govern the shape of the flood hydrograph. This detailed knowledge of the processes of generation of runoff on watersheds will result in more accurate methods of predicting flood flows and water yields. (SWC 2-a3)

At Riesel, Texas, unit graphs of runoff rate distribution from a 132-acre watershed were developed for an early period of nonconservation treatment and for the present period of conservation treatment. Comparison of the two shows that the peak rate of runoff was reduced from 2.23 to 1.18 inches per hour as a result of conservation treatment while the time to peak remained at 24 minutes. The unit graphs also show an increase in time for equal percentages of runoff to pass the station. (SWC 2-e3)

At Chickasha, Oklahoma, an analytical study is being made of historical flows along the main stem of the Washita River to determine parameters characterizing regime flows prior to development of upstream flood abatement programs and as a basis for a preliminary estimate of changes in flow regime which might result from a maximum watershed development program. This study will also provide a base for comparison with later documented main stem flows in evaluating effects of installed tributary development programs in the Anadarko-Alex study reach. All available measured storm flow hydrographs for main stem gaging stations for the 10-year period 1941-50 are being used in this study. The flow routing constants derived for actual conditions in the period will be used to synthesize new hydrographs for the same storms, but using tributary discharges estimated as if land use and management changes and flood-retarding structures were in effect. This exploratory study is being developed in especially close association with the Soil Conservation Service. (SWC 2-e3)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Holtan, Heggie N., Minshall, Neal E., and Harrold, Lloyd L. 1962. Field manual for research in agricultural hydrology. U.S. Dept. Agr. Agr Handbk. 224: 215 pp.

Precipitation Patterns

Harrold, Lloyd L. and Dreibelbis, F. R. 1962. Errors in evaluations of dew amounts by the Coshocton Lysimeter. Internatl. J. Hydrol. 2(3): 73.
Hershfield, David M. 1962. Closing Discussion: "Estimating the probable maximum precipitation" by David M. Hershfield, American Society of Civil Engineers Proceedings paper #2933, September 1961. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-4): 283-284.
Hershfield, David M. 1962. Effective rainfall. U.S. Dept. of Commerce Weather Bureau Weekly Weather & Crop B.: 7-8.
Hershfield, David M. 1962. Extreme rainfall relationships. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-6): 73-92.
Hershfield, David M. 1962. A note of the variability of annual precipitation. J. Appl. Met. 1(4): 575-578.
Neff, Earl Lock, and Bloomsburg, George L. 1962. Precipitation Characteristics in the Palouse Area of Idaho and Washington. U.S. Dept Agr. ARS 41-66: 16 pp.

Soil Moisture Accretion and Depletion

Dreibelbis, F. R. 1962. Some aspects of watershed hydrology as determined from soil moisture data. Jour. Geophys. Res. 67: 3425-3435. Abstract Jour. Geophys. Res. 67: 3554.
Hamon W. Russell. 1962. Closing Discussion: "Estimating potential evapotranspiration" by W. Russell Hamon, American Society of Civil Engineers Proceedings paper #2817, May 1961. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-4): 245-247.
Harrold, Lloyd L. 1962. Application of lysimeter data to studies in watershed hydrology. 2nd Canadian Hydrology Symp. Proc. 2: 128-134.

Aquifer-Streamflow Relationships

Stephens, John C. 1963. Report on Diamond Jubilee Anniversary "Progress by Design" of the Florida Agricultural Experiment Stations. I. Resources. 2. Water. a. Ground Water. IV. Services. E. Central and southern Florida Flood Control. Fla. Agr. Expt. Sta. Sunshine State Agr. Res. Rpt. 8(1): 8, 160-161.

Water Yield and Water Supply and Quality

Allis, John A. 1962. Comparison of storm runoff volumes from small, single-crop watersheds and from a larger, mixed-crop watershed. Agr. Engin. 43: 220-223.

Allis, John A., and Kuhlman, Armine R. 1962. Runoff and sediment yield studies on rangeland watersheds. J. Soil and Water Conserv. 17: 68-71.

Brakensiek, D. L., and Amerman, C. R. 1962. Discussion: "An improved statistical model for evaluating parameters affecting water yields of river basins" by B. Harris, A. L. Sharp, A. E. Gibbs, and W. J. Owen. Volume 66, No. 10, October 1961, Journal of Geophysical Research. Jour. Geophys. Res. 67: 3638-3639.

Cooper, Charles F. 1962. Book Review: "Private grazing and public lands" by Wesley Calef, 292 pp. 1960, University of Chicago Press, Chicago. Ecology 43: 354-355.

Donnan, William W., and Sharp, A. L. 1962. Water. In U.S. Dept. Agr. Yearbook of Agriculture 1962; After a Hundred Years: 181-186 pp.

Harrold, L. L., Brakensiek, D. L., McGuinness, J. L., Amerman, C. R., and Dreibelbis, F. R. 1962. Influence of land use and treatment on the hydrology of small watersheds at Coshocton, Ohio, 1938-1957. USDA Tech. B. 1256: 194 pp.

Keppel, R. V., and Renard, K. G. 1962. Transmission losses in ephemeral stream beds. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88 (HY-3): 59-68.

Sharp, A. L., and Saxton, K. E. 1962. Transmission losses in natural stream valleys. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88 (HY-5): 121-142.

Keppel, R. V., Gardner, J. L. 1963. Walnut Gulch Experimental Watershed, Southwest Watershed Research Center. Ariz. Agr. Expt. Sta. Brochure: 12 pp.

Neuberger, J. W., and Sharp, A. L. 1963. Improved staff gage system for reservoirs. Agr. Engin. 44: 86-87.

Flood Flows and Storm Runoff

Brakensiek, D. L. 1962. Discussion: "General solution for open channel profiles" by James A. Liggett, American Society of Civil Engineers Proceedings paper #2983, November 1961. Amer. Soc. Civ Engin. Proc., Hydraul. Div. Jourl. 88(HY-3): 255-257.

Harrold, Lloyd L. 1962. Peak flows and corresponding maximum probable hydrograph (MPH) for small agricultural watersheds. (Abstract). Amer. Geophys. Union Mtg. Announc., Washington, D. C., April 25-28, 1962, Program Absts: p. 78.

Harrold, L. L., 1962. Studies in -- hydrology of agricultural watersheds, Coshocton, Ohio. Ohio Agr. Expt. Sta. Brochure: 16 pp.

Harrold, Lloyd L. 1962. Estimating flood volumes and hydrographs corresponding to peak flows of given frequencies for small agricultural watersheds. J. Geophys. Res. 67: 4341-4346.

Hickok, Robert B. 1963. Hydrology research needs for upstream flood prevention. Internatl. Comm. Irrig. Drain. Proc. 5th Congr. 18: 509-521 pp.

Johnson, Martin L. 1962. Watershed research for the northeast points up water conservation needs. USDA Soil Conserv. 27: 237-238 pp.

Minshall, Neal E., and Woolhiser, D. A. 1962. Discussion: "Unit Hydrograph characteristics for sewered areas" by Peter S. Eagleson, American Society of Civil Engineers Proceedings paper #3069. Amer. Soc. Civ. Engin. Hydraul. Div. Jour. 88(HY-6): 184-186.

Neff, Earl Lock. 1963. Plotting positions for logarithmic-normal frequency studies. U.S. Dept. Agr. ARS 41-77: 12 pp.

AREA 3: HYDRAULICS OF IRRIGATION, DRAINAGE AND WATERSHED STRUCTURES, CHANNELS AND FACILITIES

Problem. Water control structures of various types represent the largest part of the public and private cost for watershed protection and development programs. They are also essential, and expensive features for irrigation and drainage developments.

Research on the hydraulic design of water control structures will reduce the possibilities of overdesign, which increases the costs unjustifiably, or underdesign, which may result in costly failure. All items of costs not required for safe functioning of structures must be eliminated.

This research includes studies to improve the hydraulic efficiency of items such as trash guards for drop inlet and closed conduit spillways; to develop devices for vortex control and dissipation of energy at spillway outlets; and to develop improved flumes, weirs, gates, and rating sections for streamflow and water discharge measurement. The hydraulic properties of various grasses and other vegetation in water channels are also determined.

It is not possible or desirable to model the many hundreds of agriculture-related water control structures built each year, as is the usual custom with the larger dams and spillways on the main river systems. This research, instead, seeks to establish principles and develop dimensionless designs which can be adapted to various site situations and size requirements on individual farms and ranches and in upstream watersheds.

USDA PROGRAM

The Division has a continuing long-term program in which hydraulic and agricultural engineers are engaged in both basic and applied research on the hydraulic performance and engineering design of water control structures and channels. The studies are oriented primarily to provide information relating to the types of structures and channels involved in group irrigation, drainage and water shed protection activities. The investigations are conducted by means of: mathematical analysis of basic physical principles; studies of models ranging in size from minatures tested in laboratory flumes to full-size replicas tested in outdoor laboratories; and scientific observations of existing structures and channels in the field. The work in progress in Arizona, Minnesota, and Oklahoma is cooperative with the State Agricultural Experiment Stations, and with the St. Anthony Falls Hydraulic Laboratory, University of Minnesota. Close working relations are also maintained with the Soil Conservation Service, Illinois State Water Survey, Minnesota State Highway Department, and Oklahoma State Highway Department.

The emphasis in Arizona is in studies of flood wave meovement in semi-desert streams; in Minnesota on development of more efficient conservation structures; and in Oklahoma on development of both more efficient conservation structures and channels.

The scientific effort devoted to this area of research totals 6.3 man-years in the reporting period. Of this number 2.2 is devoted to basic studies of hydraulic phenomena; 2.8 to criteria for hydraulic design of water control structures; 0.3 to hydraulics of waterways and vegetative channels; and 1.0 to flow measurements and water metering devices.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Studies of Hydraulic Phenomena

Tests at the St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota, have previously established the similitude between air and water for studying the crest loss coefficient of the two-way drop inlet to closed conduit spillways and the greater efficiency of air models in these studies. The crest loss coefficient describes the energy loss that occurs between the headpool surface and the mid-height of the drop inlet. It depends on the drop inlet length, the crest thickness, the anti-vortex plate height, and the anti-vortex plate overhang. Most of the air model tests in 1962 were conducted to determine how the plate overhang affects the crest loss coefficient. The studies showed the effect of plate overhan to be negligible for low plate settings and slight but measurable for high plate settings. Thus, it has been shown that the overhang of the plate may be choosen to conform to the most economical construction design. (SWC 3-c1)

At Stillwater, Oklahoma, studies were made to compare the theoretically predicted flood wave velocity with that observed in a 607-foot reach of Bermudagrass-lined channel having a bottom width of 8 feet, 3 to 1 side slopes and a bed slope of 0.2 percent. The wave induced by rapidly increasing the channel discharge from about 11 to 51 c.f.s. traversed the reach with a velocity of 2.75 feet per second as compared to a theoretical wave celerity of 3.22 feet per second. When this difference is explained, it is expected that more precise techniques for designing grass-lined channels will result. (SWC 3-e1)

The mechanics of flood wave propagation is receiving special study in the Walnut Gulch Experimental Watershed at Tombstone, Arizona. This watershed is typical of semidesert watersheds in the southwest, where it has been found that many of the concepts about flood flows appear invalid. Observations in the experimental watershed last year further confirmed the importance of impulse wave travel rather than steady-state flow as the determinant of hydrograph timing and peak flow rates in these ephemeral sand bed channels. Only one flow event was large enough to provide

meaningful data during the year. In this case, the wave front of a flow having a peak discharge of 1840 c.f.s. at the entrance of a 7700-foot channel reach traversed the reach with an average velocity of 5.34 feet per second, whereas the peak moved through the reach at an average velocity of 9.16 feet per second. Absorption of a part of the flow by the dry, porous channel alluvium is probably responsible for the low velocity of the wave front on the dry channel bed. When the channel flow became established in the reach, the wave peak moved at a much greater velocity. (SWC 3-g1)

B. Criteria for Hydraulic Design of Water Control Structures

In model studies at the St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota, the hood inlet used on a 4-inch corrugated lucite pipe geometrically similar to a 48-inch corrugated metal pipe caused the pipe to fill near the entrance. The filling action was very similar to that previously reported for smooth pipes, but the corrugations caused the flow to separate from the crown when the inlet head and the discharge were low, with the result that the pipe flowed only partially full for much of its length. The pipe filled as the inlet head and the discharge increased. Surface tension was investigated and rejected as a cause of this break in flow. The phenomenon has not been observed on other inlet forms because none of them permits the inlet to seal at such low flows as does the hood inlet. (SWC 3-c1)

Studies at the Laboratory, also showed that the splitter-type anti-vortex wall for a hood drop inlet two pipe diameters square (2D) should have a minimum height above the drop inlet crest of 1D. The splitter may extend into the box if desired. These tests also showed that erosive currents working on the earthen face of the dam can be stopped by extending the splitter wall into the earth fill. (SWC 3-c1)

At Stillwater, Oklahoma, tests on a 10-inch-diameter smooth pipe with a hood inlet entrance confirmed the results of tests on small models made of lucite pipe. Tests on 24-inch-diameter corrugated pipe and 12-inch-diameter helical corrugated pipe with hood inlet entrances disclosed they did not perform the same as the smooth, lucite model. This difference was attributed to surface discontinuities in the pipe wall causing separation of the water from the pipe crown. Similar anomalies in flow patterns have also been observed in models of corrugated pipe made of lucite material. (SWC 3-e2)

At Stillwater, Oklahoma, three debris guards for drop inlet spillways were model tested for performance. A rectangular, open top design showed the smallest reduction in capacity when tested with a hay-like debris. A square, three-way inlet showed the greatest reduction in capacity and was the least efficient of the designs tested. (SWC 3-e2)

C. Hydraulics of Waterways and Vegetated Channels

Studies were initiated at Stillwater, Oklahoma to improve the procedures for the design of agricultural conservation waterways, including diversions and similar channels. At present, such channels are designed by steady, uniform flow methods modified by field observation and experience. Since flows usually enter such channels along their entire length, they are spatially varied and the traditional assumption of steady-state flow conditions is unrealistic. If channels designed on this basis have proved to be adequate in the past, then it has been due to the compensating effects of using retardance coefficients that were lower than the actual values. When true values of retardance coefficients are used with steady-state flow equations, the result is a channel that is too large. The experimental setup is being constructed to verify the mathematical analysis of spatially varied flow in an effort to improve criteria for the design of agricultural conservation channels. (SWC 3-e1)

D. Flow Measurement and Water Metering Devices

At Stillwater, Oklahoma, model tests of the Switzer Creek weir located in Cohocton, New York, were compared with current meter ratings made in the field. The good agreement between the two ratings verified the model testing technique and proved the validity of weir ratings determined by model tests. (SWC 3-e1)

At Stillwater, Oklahoma, model studies were made of a number of proposed designs for a stilling basin for Flume 1, Walnut Gulch, Tombstone, Arizona. These studies determined the minimum size of basin required and effected savings in the estimated construction costs of the runoff measuring flume. (SWC 3-e1)

At Stillwater, Oklahoma, model studies of the rate-measuring flume at Site 3, Walnut Gulch, Tombstone, Arizona, included trying different roughnesses in the approach channel, thus affecting approach velocity. These studies disclosed that a 32-percent increase in the Manning's "n" value for the approach channel reduced the discharge by a maximum of 3.8 percent. This relative independence of the flume on the approach channel velocity is a highly desirable performance characteristic that permits confidence in the accuracy of the flume. (SWC 3-e1)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Studies of Hydraulic Phenomena

Blaisdell, Fred W. 1963. Discussion: "Boundary shear stresses in curved trapezoidal channels" by Arthur T. Ippen and Philip A. Drinker, American Society of Civil Engineers Proceedings paper #3273, September 1962. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 89(HY-2): 190-191.

Criteria for Hydraulic Design of Water Control Structures

Blaisdell, Fred W. 1962. Closing Discussion: "Hood inlet for closed conduit spillways" by Fred W. Blaisdell, American Society of Civil Engineers Proceedings paper #2478, May 1960. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 88(HY-4): 197-207.

Blaisdell, Fred W. 1963. Discussion: "Side-channel spillway design" by Harold S. Farney and Adolfs Marcus, American Society of Civil Engineers Proceedings paper #3143, May 1962. Amer. Soc. Civ. Engin. Proc., Hydraul. Div. Jour. 89(HY-1): 227-228.

Flow Measurement and Water Metering Devices

Osborn, H. B., Keppel, R. V., and Renard, K. G. 1963. Field performance of large critical-depth flumes for measuring runoff from semiarid rangelands. U.S. Dept. Agr. ARS 41-69: 14 pp.

AREA 4: CONSERVATION OF WATER SUPPLIES FOR AGRICULTURAL USE

Problem. About 360,000,000 acre-feet of water was used in the United States during 1960. An increase of over 50 percent is expected during the next 15 years. Irrigated agriculture currently uses about 190,000,000 acre-feet to supply an irrigation water requirement of 114,000,000 acre-feet. The difference, 76,000,000 acre-feet, is lost to the farmer largely through seepage, evaporation, use by nonbeneficial plants, and wasteful runoff during irrigation.

Falling water tables resulting from withdrawals exceeding recharge are increasing pumping costs and the danger of depletion of supply over an appreciable area.

The conversion of cropland to grazing land requires an adequate livestock water supply strategically located to preserve the newly developed pastures. This is also a critical problem on many established dryland grazing areas.

Increased competition from industry and domestic users for a limited water supply requires the development of new sources of supply as well as increased efficiency in the collection, storage, conveyance, and use of existing supplies.

USDA PROGRAM

The Division conducts both basic and applied research and development in the area of water conservation utilizing agricultural and hydraulic engineers, soil physicists and chemists, and geologists. At the U.S. Water Conservation Laboratory, Tempe, Arizona, the research and development effort is directed toward the control of seepage from storage and conveyance structures; suppression of evaporation from soil, water, and plant surfaces; water harvest procedures, materials, and storage structures; water measurement; and ground water recharge. In Nevada, work is concerned with seepage control using bentonites, water salvage from phreatophytes, and the establishment of replacement vegetation of economic value. Centers for ground water recharge are in the Central Valley of California and the High Plains of Texas. Development studies of seepage control, and precipitation water harvest and storage by use of artificial rubber, plastics, and asphaltic-impregnated fabrics are underway in Utah. Water-measuring devices are under study and development in Colorado. Farm pond size in relation to water yield and the magnitude of losses is under study in Missouri and Georgia. Pond sealing methods are included in the Missouri studies, and the development of dug ponds to tap shallow aquifers in the Georgia studies.

The field station work is in cooperation with the state experiment stations or other state agencies in the states in which the work is located. A P.L. 480 research project on methods for desilting runoff for ground water recharge was started with the Israel Institute of Technology, Technion, Israel. The scientific and engineering effort in this area totals 23.0 professional man-years per year. Of this total 9.7 are devoted to control of seepage and suppression of evaporation from surfaces; 5.2 to development of farm water supplies, related equipment, and water measurement; 7.2 to methods, practices, and devices for ground water recharge (including 1.4 for the P.L. 480 study); and 0.9 to reclaiming and reuse of wasted waters (phreatophytes).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Control of Seepage and Suppression of Evaporation from Surfaces

1. Seepage. Work at the U.S. Water Conservation Laboratory has extended the principles of the falling head seepage meter technique so that seepage can now be measured under a wide variety of conditions. The principles have also been reduced to simple procedures for making routine seepage measurements in the field. The falling head meters can not be used for measuring seepage losses, for evaluating soil sealants to reduce seepage, and for ground water recharge investigations.

Electrical analog studies at the U. S. Water Conservation Laboratory have shown that for most conditions seepage through canal walls is increased by lining only the bottom, and the total seepage loss is nearly as great as before lining. Thus, the entire canal must be lined to secure substantial seepage reduction unless a canal is very shallow.

Principles and procedures have been developed at the U.S. Water Conservation Laboratory for measuring the vertical and horizontal hydraulic conductivity of undisturbed soil in the field. The principles of the double-tube method, as previously reported, were extended to determine the relation of vertical and horizontal conductivity to the total conductivity measured with the original double-tube procedure. A standard double-tube measurement combined with a simple measurement of vertical conductivity now permits the calculation of horizontal conductivity.

Studies at the U.S. Water Conservation Laboratory have shown that clay soils can be deflocculated to a controlled degree to reduce seepage without creating an erosion problem. Use of deflocculating salts to reduce seepage where compacting equipment can now be used, frequently has resulted in failure because the surface soil was completely dispersed and washed away. Proper analysis of the soil, combined with adequate knowledge of the soil chemical-physical relationships, will permit

selecting the type, quantity, and placement of salt to partially, but not completely, break down the soil structure.

A modified cationic asphalt emulsion which bonds very well to concrete canal linings with a surface coating of silt and algae has been developed at the U.S. Water Conservation Laboratory. Repair of cracked concrete linings has in the past been very difficult because sealing materials would not bond unless the concrete was thoroughly cleaned. (SWC 4-gG1)

At Logan, Utah, laboratory, model, and field testing of materials for use as canal linings continued to emphasize their value for seepage control. Buried 8-mil. vinyl installed in 1955 provided the same almost complete control as when installed. Vinyl linings exposed above the operating water level deteriorated, but that part of the lining continuously under water has remained in good condition. Both earth linings (10-14 years old) and asphaltic membrane linings (12 years old) installed at the River Laboratory in Logan, Utah, continued to provide appreciable seepage control, although a markedly decreased effectiveness has developed through the years.

The effectiveness of cyanoethylation in preventing biological deterioration of burlap was further substantiated in the Utah studies. Based on laboratory compost studies, treatment with copper naphanate was also effective, but to a lesser degree. The comparable effectiveness of copper naphanate when added with the asphalt saturate required for seepage prevention eliminates a separate operation in the fabricating process and thus reduces the cost of rot-proofing.

Field studies near Fallon, Nevada, showed a good initial seal with a 2-pound application of bentonite dry-mixed into a 4-inch stratum of permeable, fine sand. Two dispersion treatments likewise formed excellent initial seals where one pound of bentonite per square foot was dispersed in the water. However, after the seals were dried and wetted five times, seepage was reduced only by 27 to 44 percent. (SWC 4-g3)

Field studies of pond sealing in Missouri showed that a good seal can be achieved either by dispersion of aggregates if present in the soil and compaction of the pond bottom or by a compacted blanket of silt loam covering the basin area. (SWC 4-c1)

2. Evaporation. An emulsion of hexadecanol and octadecanol which appears to be more effective than previously used flakes and powders for reducing evaporation from water surfaces has been developed at the U.S. Water Conservation Laboratory. The emulsion is extremely stable and has not broken down during freezing, heating to 140° F., or storage for over 1 year. Tests in small water containers exposed on the roof of a building showed evaporation reductions of 37 percent for flakes and 44 percent for the emulsion. These test results seem quite promising in view of the fact that simple devices can be used to apply the emulsion to water surfaces. (SWC 4-gG2)

At Logan, Utah, the effectiveness of a floating film for evaporation control has been demonstrated. Most promising is a polyethylene film structure with multiple entrapped air spaces. The structure has a high degree of buoyancy and resists wrinkling and submergence. The evaporation control effected is approximately proportional to the area covered. (SWC 4-g1)

The miniature net radiometer developed at the U.S. Water Conservation Laboratory has been improved so that actual radiation values can now be directly recorded. Previous instruments of this type required direct recording of electrical output and later computation to convert recorded output to units of radiation. This improvement was achieved by increasing the electrical output of the radiometer and modifying the circuit with resistors which cause the electrical output to coincide exactly with the radiation units being measured.

A very simple direct weighing and reading evapotranspirometer (lysimeter) has been successfully designed and tested at the U.S. Water Conservation Laboratory. A metal container of 1 cubic meter is supported at one point by a standard strain gage load cell. The change in weight on the load cell is measured with a portable instrument and gives the loss of water directly in millimeters. The accuracy is 0.5 mm. sufficient to obtain highly accurate weekly data on water loss and quite acceptable daily data during periods of large evaporation. The device weighs about 1800 kg; has a suspension of negligible friction; requires no power, maintenance, or calibration; and may be flooded over when required. A suction-type drainage system is provided for the control of soil moisture.

Seedheads on sudangrass considerably reduced evapotranspiration in studies at the U.S. Water Conservation Laboratory. The seedheads, not being able to transpire, absorbed a portion of the radiant energy striking the crop, converted it to sensible heat which was lost to the atmosphere without evaporating water, and formed an effective aerodynamic barrier against transfer of heat to the transpiring leaves. This difference was not due to physiological changes in the leaves because transpiration increased to a normal level when the surrounding crop was cut so that radiation and warm air could reach the leaves.

Precise measurements of evaporation losses from sudan grass in weighing lysimeters at the U.S. Water Conservation Laboratory showed that, with ample soil moisture, the ability of the crop to absorb water from the soil and transport it to the evaporating leaf surfaces never limited evapotranspiration. This was true in spite of very high evaporative demand and rates of loss up to 1.7 millimeters of water per hour and 17 millimeters per day. (SWC 4-gG2)

Infiltration of water into soil was directly influenced by temperature in experiments conducted at the U.S. Water Conservation Laboratory. Movement of water into uniform columns of Adelanto loam, Pachappa loam, and Pine silty clay was measured in studies where temperature was the only variable. The effect of temperature on the relationship between surface tension and viscosity appears to be the dominant factor. The square foot of the surface tension-viscosity ratio adequately accounts for the variation of infiltration with temperature. A small reduction in total porosity materially reduced the infiltration rate of these soils. (SWC 4-gG4)

B. Development of Farm Water Supplies and Related Equipment

1. Water harvest. Ground covers for rainfall catchment areas under observation at three locations both in the Green Canyon and in the Fishlake National Forest of Utah have continued to give generally good performance. Butyl ground covers have withstood weathering and aging better than either black vinyl or asphalt-coated jute, although all are effective in catching precipitation and producing runoff. A polyisobutylene ground cover under test for less than one year is of special interest because of its projected low cost of 35 cents per square yard in place. Accelerated aging tests indicate it has potential.

Development studies in Utah have shown butyl bags to be practical for storing of water collected from rainfall catchment ground covers in water-short areas. Both seepage and evaporation are eliminated. Capacity is presently limited to 50,000 gallons. (SWC 4-g3)

Equipment and materials have been developed at the U.S. Water Conservation Laboratory for constructing low-cost water harvesting pavements by spraying the soil with asphaltic compounds designed for penetration and high strength. The materials are applied with a 25-foot, high capacity, spray boom at a rate of 1,250 square feet per minute. A tough asphalt-soil pavement is created which has a bearing strength of 1,000 pounds per square inch. Cost of materials and application for the pavement is 12 cents per square yard. Other costs, such as site preparation and soil sterilant, bring the total cost of this water harvest treatment to about 25 cents per square yard. This treatment is expected to produce water in a 20-inch rainfall zone for 30 cents per 1,000 gallons. (SWC 4-gG3)

Preliminary studies at Tifton, Georgia, on the Coastal Plain soils, show that ponds for storing surface runoff and pits for storing shallow subsurface seepage water have definite limitations in the quantity of water available for use. Further studies will be oriented to provide information so the design of water storage facilities on farms can be equated against the available water and intended use. (SWC 4-b1)

2. Water measurement. Trapezoidal flumes developed in Colorado for measurement of water can be made an integral part of a concrete irrigation channel at the time the ditch is constructed or can be formed of plastic or metal for placement in the ditch after the concrete is set. The flume has plane surfaces and is easily constructed. Hydraulic tests indicate that the flume can operate under a high degree of submergence without discharge corrections being necessary. This is a very desirable feature since corrections for submergence are usually cumbersome to make and thus in many cases are not made at all. Nearly trouble-free operation is possible because of minimum obstruction to debris carried in the irrigation water.

Full-scale model tests of a constant head orifice for measurement of irrigation water were conducted in the Hydraulics Laboratory at Fort Collins, Colorado, as a result of farmers' complaints of water deliveries up to 50 percent less than indicated. The tests indicated a maximum difference of 4 percent over the operating range of the device. However, when the orifice was plugged with tumbleweeds, discharges were reduced up to 45 percent of that indicated. Design has been improved to facilitate ease and accuracy of reading the differential head across the orifice gate. (SWC 4-d1)

Discharge equations for flow meters made of standard 3-inch-diameter commercial pipe elbows can now be calculated with less than 5 percent error by methods developed by the U.S. Water Conservation Laboratory. The meters use the difference in pressure between the inside and outside of the elbow, caused by centrifugal force on the water being turned by the elbow, as a measure of flow rate. Discharge equations can be calculated if the diameter and radius of curvature are known. The radius of curvature is very difficult to measure because the elbows are cast in sand molds and the curves are not uniform. Calculations based on the manufacturer's dimensions are often in error by more than 10 percent. The error was reduced to a maximum of 4.3 percent by measuring the volume of the elbow by filling it with water and then calculating the radius of curvature by assuming the elbow to be one-fourth of a true torus.

Significant improvement in the detection of chemical tracers used to measure the flow of water in pipes and open channels has resulted from work conducted at the U.S. Water Conservation Laboratory. The method involves adding a known quantity of a chemical to the flowing water and measuring the concentration at some point downstream. The quantity of flowing water is proportional to the dilution of the tracer, i.e., the greater the flow the greater the dilution. Sensitive laboratory equipment and procedures for measuring fluorescent tracers have been modified to permit their use in the field. Field tests have shown that the equipment and procedures are reliable and that quantitative measurements of the tracer in the 16 parts per billion range can be made with less than 1 percent error. (SWC 4-gG5)

C. Methods, Practices, and Devices for Ground Water Recharge

Laboratory studies with columns of uniform sands at the Ground Water Recharge Center, Fresno, California, show that the velocity and hydraulic conductivity increase linearly with an increase in grain size for the size range 0.10 to 1.00 mm; that, although total porosities vary only slightly, velocity and hydraulic conductivity values cover a wide range because of pore size; that particle rearrangement of the soil-water interface may significantly reduce infiltration; that particle rearrangement of the sand-water interface may be stabilized by a layer of coarse sand; and that the position and thickness of layers of low hydraulic conductivity significantly influence the velocity, hydraulic gradient, and the hydraulic conductivity of the system.

Field data obtained on the buildup and dissipation of a ground water mound beneath a 2-acre square in southwestern Fresno County, California, revealed low intakes and rising perched water table conditions, indicating the soil profile was not suited for artificial recharge by the over irrigation method and that an expansion of the irrigated area could result in a rise of the water table to the point where drainage would be required.

Exploratory studies indicate natural tritium fallout from post atomic tests might be used to trace the rate of ground water flow in deep aquifers across San Joaquin Valley, California. Two preliminary samples from wells 15 miles apart show that a relatively high tritium water loss passed one well but not the others. Additional sampling should determine the rate of movement of the high tritium front. (SWC 4-g2)

Studies at the U.S. Water Conservation Laboratory have shown that generalized assumptions cannot be made concerning the effect of ground water mounds on seepage from a ground water recharge basin. A rising mound can increase, decrease, or not affect at all the recharge rate of the basin, depending upon the relation between permeability of the pit bottom and permeability of the underlying soil. This suggests that each indiviaual recharge site be modelled on an electrical analog to assure field results in conformity with assumptions made in design calculations. (SWC 4-gG3)

As an aid to relating soil characteristics to water movement a permeameter was developed at the Fresno, California, Ground Water Recharge Center which permits determination of initial soil moisture content, transmission rate, gain in soil moisture with time, percolation rate, Darcy velocity, hydraulic conductivity, and saturation. The permeameter utilizes soil cores 0.5 foot long by 2 inches in diameter obtained from strata at any depth by drill rigs.

Another instrument developed at the Center provides a rapid measure of hydraulic conductivity by following the change in strain of a metal diaphragm instrumented with resistance strain gages, as a small volume

of water is displaced through a soil core under a falling head (produced by the distended diaphragm). This method is capable of evaluating the hydraulic conductivity of soil cores to within an accuracy of 2 to 3 percent. Observations indicate the reliability of core conductivities rests in the nature of the core itself rather than in instrumental error. The device is particularly adapted to the determination of very low hydraulic conductivities in a practical length of time. (SWC 4-g2)

At Bushland, Texas, a sediment removal system was designed to remove suspended clay from playa lake water. The treatment consisted of Nalco 600 flocculant, slow mixing by baffles in a level irrigation ditch, settlement of flocculated material in the ditch, and filtering through a sand filter to effectively remove all sediment from the water. Although the capacity of the system was quite low, the principle of the system was found to be sound. (SWC 4-e1)

D. Reclaiming and Reuse of Wasted Water (Phreatophytes)

Studies to determine the feasibility of establishing replacement vegetation of higher economic value in phreatophyte areas of the Humboldt River Valley of northern Nevada indicated that seasonal water table fluctuations are minor and should not be a hindrance to the establishment of a beneficial replacement phreatophyte specie. Depths to water table during the growing season favor a deep-rooted specie such as tall wheatgrass or alfalfa. Soil intake rates on most of the nonplaya soils are more than adequate for efficient sprinkler irrigation. Twice weekly irrigations appeared to be slightly better than once weekly irrigations. Irrigation was required beyond seedling emergence. The quality of the shallow water table is more than adequate for supplemental irrigations to aid establishment of replacement vegetation. It has a medium salinity hazard and low sodium hazard. On playa soil, establishment of a replacement vegetation is questionable owing to the low intake rate and high salinity--alkalinity. Reclamation appears economically unfeasible due to lack of abundant leaching water.

The average daily use of water by native meadow grasses growing in lysimeters located in the Humboldt River Valley near Winnemucca, Nevada, was 0.154 inch prior to hay harvest. The average hay yield was 1.5 tons per acre. Following hay harvest the grasses continued to use water but at the reduced rate of 0.069 inch per day. A direct linear relation was found between hay produced and the water evapotranspired to produce it where there was a constant water table depth of 4 feet. Diurnal fluctuations of shallow water tables in native grass areas of desert environment indicated that the grasses withdrew water from the capillary fringe or water table until it dropped to about 7 feet from the surface. When the water table dropped below this depth the grasses survived only by depleting the soil moisture in the soil profile above the water table and caused little or no change in depth to water table. (SWC 4-g1)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Control of Seepage and Suppression of Evaporation from Surfaces

Bouwer, Herman. 1962. Closing discussion: Variable head technique for seepage meters. Proc. Amer. Soc. Civ. Eng., Jour. Irrig. and Drain. Div 88 (IR-2): 91-94.

Bouwer, Herman. 1962. Effect of velocity on seepage and its measurement. Proc. Amer. Soc. Civ. Eng., Jour. Irrig. and Drain. Div. 88 (IR-3): 1-14.

Bouwer, Herman. 1962. Field determination of hydraulic conductivity above a water table with a double-tube method. Soil Sci. Soc. Amer. Proc. 26 (4): 330-335.

Bouwer, Herman. 1962. Seepage meters in seepage and recharge studies. Proc. Amer. Soc. Civil Eng., Jour. Irrig. and Drain. Div. 89 (IR-I): 17-42.

Bouwer, Herman. 1963 Theoretical effect of unequal water levels on the infiltration rate determined with buffered cylinder infiltrometers. Jour. Hydrol. 1: 29-34.

Denmead, O. T., Fritschen, L. J., and Shaw, R. H. 1962. Spatial distribution of net radiation in a corn field. Agron. Jour. 54 (6): 505-510.

Erie, Leonard J. 1962. Evaluation of infiltration measurements. Agr. Eng. 5 (1): 11-13.

Fritschen, Leo J., and van Bavel, C. H. M. 1962. Energy balance components of evaporating surfaces in arid lands. Jour. Geophysical Res. 67 (13): 5179-5185.

Fritschen, Leo J. 1963. Construction and evaluation of a miniature net radiometer. Jour. of Applied Meteorol. 2(1): 165-172.

Fritschen, Leo J., and van Bavel, C. H. M. 1963. Micrometeorological data handling system. Jour. of Applied Meteorol. 2(1): 151-155.

Hawes, Frank, and Lauritzen, C. W. 1962. New slipform uses free-flow hopper. Utah Farm and Home Sci. 23 (3): 63-65.

Humphreys, A. S., and Lauritzen, C. W. 1962. Shape factors for hydraulic design of lay-flat irrigation tubing. Trans. Amer. Soc. Agr. Eng. 5 (2): 175-179.

Jamison, V. C., and Thornton, J. F. 1963. Sealing farm ponds in Missouri. Missouri Agr. Expt. Sta. Res. Bul. 817.

Jackson, R. D., Reginato, R. J., and Reeves, W. E. 1962. A mechanized device for packing soil columns. U.S. Department of Agriculture, ARS 41-52, 10 pp.

Nakayama, F. S., and Scott, A. D. 1962. Gas sorption by soils and clay minerals: I. Solubility of oxygen in moist materials. Soil Sci. 94 (2): 106-110.

Nakayama, F. S., and Scott, A. D. 1962. Gas sorption by soils and clay minerals: II. Capillary effects. Soil Sci. 94 (5): 292-296.

Nakayama, F. S., and Jackson, R. D. 1963. Diffusion of tritiated water (H^3HO^{16}) in Agar Gel and water. Jour. Phys. Chem. 67: 932.

van Bavel, C. H. M. 1962. Accuracy and source strength in soil moisture neutron probes. Soil Sci. Soc. Amer. Proc. 26 (4): 405.
van Bavel, C. H. M. 1962. Light-weight rate meter for neutron soil moisture measurement. Soil Sci. 94 (6): 418-419.
van Bavel, C. H. M., and Myers, L. E. 1962. An automatic weighing lysimeter. Agr. Eng. 43 (10): 580-583, 586-588.
Jensen, M. E., and Haise, H. R. 1962. Discussion: Evaporation from Pyramid and Winnemucca Lakes, Nevada. Proc. Amer. Soc. Civ. Eng. 88 (IR-2): 119-122.

Development of Farm Water Supplies and Related Equipment

Lauritzen, C. W. 1962. Graze more range with this new water-saving idea. Ford Farming, p. 22.
Myers, Lloyd E. 1962. Water harvesting. 16th Annual Nevada Water Conf., Carson City, Nev., 12 pp. (Mimeo.).
Myers, Lloyd E. 1963. Water conservation--a research challenge. Jour. Soil and Water Conserv. 18 (1): 31-34.
Robinson, A. R. 1962. Closing discussion: Vortex tube sand trap. Amer. Soc. Civil Eng. Trans., Vol. 127, Part III.
Robinson, A. R., and Chamberlain, A. R. 1962. Flow measurement in open channels. Colorado State Univ. Eng. Dept. CER62ARR-ARC 4, 17 pp.
Robinson, A. R., and Liu, Henry. 1962. Discussion: Unification of Parshall flume data. Amer. Soc. Civil Eng.,Jour. Irrig. and Drain. Div. 88 (IR-2): 112-114, Part I.

Methods, Practices, and Devices for Ground Water Recharge

Bianchi, W. C. 1962. Measuring soil moisture tension changes. Agr. Eng. 43: 398-399, 404.
Bianchi, W. C., Haskell, E. E., Jr., and Johnston, William R. 1962. A soil-drainage study in southwestern Fresno County. Hilgardia 33: 171-178.
Bianchi, W. C., and Johnston, William R. 1962. An inexpensive water stage recorder for use in determining hydraulic conductivity of soil by the auger hole method. Agr. Eng. 43: 223-227.
Bouwer, Herman. 1962. Analyzing ground-water mounds by resistance network. Amer. Soc. Civil Eng., Jour. Irrig. and Drain. Div. 88 (IR-3): 15-36.
Bouwer, Herman. 1962. Seepage meters in seepage and recharge studies. Amer. Soc. Civil Eng., Jour. Irrig. and Drain. Div. 89 (IR-1): 17-42.
Bouwer, Herman. 1963. The flow system below a water spreading basin. Proc. Internatl. Comm. Irrig. and Drain. 5th Cong. 18: 89-106.
Dylla, A. S., and Tovey, Rhys. 1962. Plastic membrane tanks for evapotranspiration determinations. Agr. Eng. 43: 584-585.
Haskell, E. E., Jr., and Bianchi, W. C. 1963. Effects of prolonged irrigation on cotton. Agr. Jour. Notes 55: 203-204.
Schiff, Leonard. 1963. Ground water recharge methods based on site characteristics and on sediment in flood water. Internatl. Comm. Irrig. Drain. Proc. 5th Cong. 18: 17-31.

AREA 5: IRRIGATION PRINCIPLES, REQUIREMENTS, PRACTICES AND FACILITIES FOR EFFICIENT USE OF WATER ON FARMS

Problem. The permanence of the agricultural economy of the Western States is dependent upon irrigation and solution of unsolved problems associated with the practice. Irrigation has become an important factor in the production of high-value crops in the humid areas where annual or seasonal droughts jeopardize both the quality and quantity of the crops. With the high off-farm imputs of modern farming, crop failures can be disastrous to the farm economy. Rigid adherence to historical methods of allocating water and the use of all allocated water is endangering future water supplies and damaging some of the most fertile soils of the west. Currently there are about 32,000,000 acres of irrigated land with a little over 90 percent located in the Western States.

Solution to many of the problems associated with the irrigation practice, such as efficient water application, optimum time and amount of application in relation to crop growth stage, climate and soil factors and a simple economical method of determining when to irrigate, would do much to increase water use efficiency. Temperature control by sprinkler irrigation to maintain high crop quality presents an almost untouched area for development and improvement.

The development of prediction equations for computing evapotranspiration (consumptive use) based on sound thermodynamic principles is needed for efficient design of irrigation systems.

The shortage of farm irrigators in many areas stresses the need for automation in irrigation water application by both sprinkler and surface methods.

USDA PROGRAM

The Division conducts both basic and applied research and development in irrigation, utilizing agricultural and hydraulic engineers, soil physicists, and soil scientists. Work concerned with consumptive use, irrigation timing, and water extraction patterns is underway in New Jersey, Alabama, Georgia, Nebraska, Wyoming, Texas, California, and Nevada; with crop response in New Jersey, Virginia, Georgia, Mississippi, Colorado, South Dakota, Wyoming, Texas, and Washington; and with water intake, transmission, and storage in Maine, Georgia, Texas, Washington, Oregon, California, and Utah. Surface irrigation hydraulics and water absorption is under study in Missouri, Colorado, Nebraska, South Dakota, Texas, Idaho, Utah, and California. Sprinkler irrigation techniques and water distribution is under study in Idaho and Nevada. System design, irrigation efficiency, and automation in application is under study in Colorado, Texas, Utah, Idaho, and Florida. This work is in cooperation with the

state experiment stations or other agencies of the states in which the work is located. A P.L. 480 program on consumptive use is underway with Hebrew University at Rehovoth, Israel. The scientific and engineering effort in this area totals 23.1 professional man-years. Of this total 13.0 are devoted to irrigation water requirements, crop response, and soil-water relations (including 1.3 for the P.L. 480 study); 4.4 to surface irrigation hydraulics and water absorption; 1.0 to sprinkler irrigation techniques and water distribution; and 4.7 to systems design for efficient use of water and of labor in water application.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Irrigation Water Requirements, Crop Response, and Soil-Water Relations

1. Consumptive use, timing, and water extraction patterns. Additional work was done during the year toward improvement of methods for predicting total irrigation water requirements for specific soil and crop conditions in arid, semiarid, and humid climates. While advective energy and deep percolation components are a part of irrigation water requirements, separation of these components from water use measurements must be done for proper evaluation of evapotranspiration from soil moisture measurements. Advances were made toward evaluation of both advective energy and deep seepage components during the year.

Potential-evapotranspiration-estimating procedures assume an infinite area of actively transpiring well-watered vegetation surrounding the site in question. This condition is generally met in humid areas but not in the arid and semiarid regions. A recent study using evaporation measurements for short periods made during the past 35 years in the 17 Western States has provided a simple empirical equation for estimating mean potential evapotranspiration. This equation considers two major variables, solar radiation and mean air temperature. Estimates using this equation agree reasonably well with lysimeter data on a weekly basis and have immediate use in predicting mean peak evapotranspiration rates for designing irrigation and distribution systems. When net radiation values are available the equation may be used for estimating the magnitude of advected energy. (SWC 5-f1 and SWC 5-d1)

Of six climatic factors and two empirical evapotranspiration formulas included in the analysis of alfalfa evapotranspiration and climatic data taken in California, evaporation from U.S. Weather Bureau pans and solar radiation correlated best with the actual evapotranspiration rates. The analysis also showed that the influence of the coastal climate reduced evapotranspiration rates approximately 40 percent during the summer months. (SWC 5-g2)

Evapotranspiration rates from irrigated cotton at Watkinsville, Georgia, were found to correlate well with solar radiation data recorded at Atlanta, Georgia, indicating that U.S. Weather Bureau records of solar radiation can be used to predict the rate of moisture

use by cotton. Evapotranspiration rates from irrigated cotton and Coastal Bermudagrass were correlated with evaporation from a standard open pan at Thorsby, Alabama, indicating that open pan evaporation also can be used to predict the rate of moisture use by these crops. (SWC 5-b1)

At Thorsby, Alabama, daily rates of moisture use by crops varied with the stage of crop growth and with the available soil moisture. The daily rate with cotton ranged from 0.09 inch on April 15 to 0.25 inch on August 1, while Coastal Bermudagrass used 0.09 inch on May 1 and 0.13 inch on June 15. (SWC 5-b1)

Procedures for separation of deep seepage from evapotranspiration in water use measurements were under development in both Utah and Washington. Preliminary results from the Washington work indicate that deep percolation may be overestimated on cropped plots by use of unadjusted values of downward movement of moisture secured from plots on which both evaporation and transpiration were prevented. (SWC 5-f1)

The moisture extraction pattern from cotton on the Hedalgo soil at Weslaco, Texas, was largely dependent upon the amount of moisture maintained in the upper 2 feet. When it was not allowed to fall below 50 percent of field capacity, moisture use from the upper 2 feet was 70 percent of total use. When moisture in this depth was allowed to fall to 10-15 percent of field capacity, moisture use from this depth was reduced to less than 60 percent. Moisture extraction was directly proportional to percent of total roots in each increment of depth. (SWC 5-e1)

2. Crop response. At New Brunswick, New Jersey, irrigation increased the yields of cabbage 7 years, sweet corn 3 years, cantaloupes 2 out of 8 years, and snap beans 2 out of 6 years. During 1962, nonirrigated cabbage yielded 13.2 tons per acre whereas cabbage, irrigated when soil moisture reached three-fourths atmosphere tension, yielded 17.0 tons per acre and had a significantly larger weight per head. The other crops did not respond favorably to irrigation this year. Irrigation has produced no measurable effect on the physical properties of the soil. Management systems included continuous cultivation, use of winter cover crops, and a 3-year rotation with sod. Use of cover crops and sod have improved the aggregate stability, bulk density, and hydraulic conductivity of this soil but have had no significant effect on yields of sweet corn or cabbage. Sod and cover crops increased the yields of snap beans but decreased the yields of cantaloupes.

At Blacksburg, Virginia, irrigation increased average forage yields of orchardgrass from 4,830 pounds per acre in the nonirrigated control to 6,259 pounds per acre. Nitrogen fertilization gave greater yield responses than did irrigation or cutting management treatments. The irrigated plots fertilized with 600 pounds of nitrogen produced three times as much

forage as the unfertilized plots. On the nonirrigated plots, application of 600 pounds of nitrogen resulted in 4.8 times as much forage as on the nonfertilized plots. As the nitrogen fertilization rate increased, nitrogen use efficiency decreased from 30 pounds of forage per pound of nitrogen at the low application rate of 50 pounds of nitrogen per acre to 10 pounds of forage per pound of nitrogen at the 600 pounds per acre rate. There was no significant interaction between irrigation and cutting management practices. (SWC 5-a1)

The increase in yield due to irrigation on 25 corn hybrids at State College, Mississippi, ranged from 12.7 to 65.0 bushels, indicating a wide genetic difference in ability to utilize moisture. The yield of flue-cured tobacco at Tifton, Georgia, was increased 300 to 500 pounds per acre with irrigation. Nitrogen rates above 50 pounds per acre caused reduction in yields with and without irrigation. Neither yield nor quality of tobacco was impaired by flooding the soil with 2 inches of water 24 hours after a normal irrigation on Tifton loamy sand. Four-year average yields of grain sorghum at Watkinsville, Georgia, were 85 and 65 bushels per acre with and without irrigation. There was no effect on stomatal behavior or moisture use by corn from 3 pounds per acre of Atrazine applied to the soil immediately after planting. (SWC 5-b1)

Studies of effect of fluctuating water tables on yield of alfalfa at Reno, Nevada, showed yield was reduced when the water table was raised by irrigation and held at the soil surface for more than 3 days. Yield dropped a little over 2 tons per acre when the time of inundation was increased from 3 to 4 days and continued to drop as the time of inundation was extended. For 1-, 2-, and 3-day inundation periods, yields were greater than that obtained by surface irrigation every 14 days but with no water table. (SWC 5-g2)

In some areas of the Columbia Basin the regrowth of alfalfa during the period after cutting is affected by a condition known as "June Yellows." Regrowth is stunted, yellow, and characteristically distorted, with some plants affected more severely than others. Cause of this condition is not known but past observations have indicated it to be related to high soil moisture levels. Results of an exploratory study at Prosser, Washington, in 1962 indicated that "June Yellows" could be induced in plots by maintaining the soil moisture at a high level prior to cutting. Future studies will be conducted to verify these results and attempt to determine why the wet condition induces "June Yellows" in alfalfa. (SWC 5-f1)

3. Water intake, transmission, and storage. At Watkinsville, Georgia, cropping sequence had no significant effect on bulk density, pore space, and pores drained in the A_p horizon of Cecil sandy loam soil, but nitrogen fertilization decreased aggregation. Infiltration rate of soil planted to corn following grass sod was higher than of soil in grass or alfalfa, and the intake rate of soil in corn was higher at harvest time than after the first cultivation because of increased ground cover from grass in the

corn rows. There was a high correlation between sand and clay content of soils and the moisture retention values for one-third and 15 atmosphere tensions, but available water capacity of the soil was not highly correlated with soil texture. (SWC 5-b1)

Available soil moisture is frequently estimated from laboratory measurements of moisture retention as the difference between water retained at one-third and 15 atmosphere tensions. Field studies of available soil moisture on 3 soils in the Columbia Basin have shown that estimates of available water based on this laboratory method can be much too low in stratified soils or soils underlain by coarse material. Available soil moisture determined in the field was 130, 130, and 104 percent greater than the laboratory estimate for the Ephrata, Timmerman, and Rupert soils, respectively. These results illustrate the limitations of some routine laboratory determinations in predicting available soil moisture. Field determinations in stratified soils can also be in error if precautions are not taken to prevent lateral movement of water from the test site. Available water in the 6- to 12-inch depth on the Ephrata and Scooteney soils where lateral flow was not prevented was only 60 percent of the values obtained when lateral flow was prevented. Plots with lateral flow prevented are more representative of field conditions. These results illustrate the importance of observing basic unsaturated flow principles in soil moisture work and will lead to improved techniques for prediction and measurement of available water holding capacities of irrigated soils. (SWC 5-f1)

At Brawley, California, it was found that radioactive gold tracer can be used for measuring water intake and that it has the advantage of measuring intake at any point within an area, whereas other methods measure average intake. The method would be useful for measuring the water intake pattern of a furrow, evaluating other methods of measuring intake, and distribution of water intake within a ring infiltrometer. In this study the radioactive tracer was not measurably lost by adsorption from the tagged water as it flowed over the soil surface. The tracer was adsorbed near the soil surface and sampling to a depth of 6 centimeters recovered 95 percent of the gold. (SWC 5-g3)

B. Surface Irrigation Hydraulics and Water Absorption

Further analysis of data compiled from laboratory investigations at Fort Collins, Colorado, concerning hydraulics of flow in irrigation borders and furrows indicates that the degree of roughness likely to exist affects resistance to both laminar and turbulent flows. Criteria were developed to determine height and spacing of roughness necessary to affect flow resistance. The value of critical Reynolds number at the transition from laminar to turbulent flow was determined for both rough and smooth boundaries. Equations to predict resistance to laminar and turbulent flow in terms of measured dimensions of boundary roughness elements give more accurate resistance values than prediction methods now used. (SWC 5-d1)

At Columbia, Missouri, study of characteristics of flow in different shaped irrigation furrows showed that the roughness coefficient was a function of the depth, hydraulic radius, velocity, and Reynolds number. The roughness coefficient decreased with an increase in each of these 4 variables. For the trapezoidal furrow, the roughness coefficient was higher than for the triangular furrow with the same degree of retardance.

The average infiltration rate was 0.12 inch per hour for the trapezoidal furrow and 0.87 inch per hour for the triangular furrow. Most of the differences in infiltration rates for the 2 furrow shapes can be attributed to the differences in depth of flow, desposition of sediment, and the ratio of wetted perimeter to width of water surface. (SWC 5-c1)

At Logan, Utah, the parameters "C" and "n" for the commonly used infiltration equation $I = CT^n$ were found to vary as water moves down a furrow. The "C" value decreases, and the "n" value increases as the furrow stream advances. As the water advances and/or increases in depth it is continually exposing new soil to initial wetting. Therefore, infiltration as measured by cylinder infiltrometers and by the water flowing in a furrow are not simply related. (SWC 5-g1)

C. Sprinkler Irrigation Techniques and Water Distribution

Sprinkler irrigation systems are currently designed using an average application rate determined by nozzle discharge, spacing of sprinkler heads on the lateral pipeline, and distance the lateral is to be moved on the main line. In operation, the application rate is not affected by lateral-move distance but is significantly influenced by the water distribution pattern of the lateral. Procedures have been developed at Boise, Idaho, for using pattern data for sprinkler heads to: (1) Select sprinkler heads and the appropriate spacing to use on the lateral that will result in application rates below the maximum a soil will absorb; (2) select the distance a lateral should be moved on the main line for maximum uniformity; and (3) compute operating time for a lateral to apply the desired depth in either the area receiving the least or the greatest amount of water, and to obtain maximum application efficiency. The procedures developed, when put to use by designers and manufacturers of equipment will greatly improve the design and performance of sprinkler irrigation systems. (SWC 5-f2)

Knowledge of the intake rate of a soil is essential for designing an economic and efficient sprinkler system. A portable device for determining intake rates using sprinkler application techniques instead of surface flooding has been developed jointly at Reno, Nevada, and Boise, Idaho. Comparison of intake rates measured with this equipment indicates that ring infiltrometers give intake rates considerably higher than the basic rate for proper sprinkler design. Accurate measurement of intake rates for soils will greatly improve the performance of sprinkler systems by preventing runoff from high areas and accumulation in depressions. (SWC 5-f2 and 5-g3)

D. Systems Design for Efficient Use of Water and of Labor in Water Application.

Low-gradient border check irrigation systems are being used where high water application efficiencies are needed. Summarization of the performance and operating data for the low-gradient border checks at Mitchell, Nebraska, has resulted in the verification of a derived theoretical equation for predicting the uniformity of irrigation. Equating this equation to the most desirable uniformity value results in an equation that can be used for selecting the optimum slope for border checks. Use of this equation will remove much of the guess work in design of "rule of thumb" procedures now used for selecting the slope of low-gradient border checks. (SWC 5-d1 and SWC 5-f2)

Field testing of automatic control gates for irrigation water developed at Boise, Idaho, continued in 1962. One of these gates provides a cutback stream for furrow irrigation. A working model of a control gate for underground and surface pipelines has been developed and is being tested. Automatic control gates for irrigation water reduce labor requirements and frequently increase water application efficiency. (SWC 5-f 2)

Experiments in the Salt River Valley, Arizona, showed that only one inadequate application of water in an otherwise optimum irrigation schedule reduced the yields of Pima S-2 and Deltapine Smooth Leaf cotton by 26 and 14 percent, respectively. The irrigation treatment was the same as the one producing maximum yields except that during one irrigation application in August the reduced yield plots were given only half as much water as the maximum yield plots. As in previous years, maximum yields were obtained by irrigating when 65 percent of the available water in the top 3 feet of soil had been used.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Irrigation Water Requirements, Crop Response and Soil-Water Relations.

Bennett, O. L. 1962. Irrigation of forage crops in Eastern United States. U. S. Department of Agriculture Prod. Res. Rpt. No. 59, 25 pp.

Criddle, W. D., Harris, Karl, and Willardson, L. S. 1962. Consumptive use and water requirements for Utah. Utah State Tech. Pub. No. 8, 47 pp.

Davis, S., Schumaker, G. A., and Pepper, J. H. 1962. Careful irrigation + adequate fertilization = fewer mosquitoes + increased production. Montana Agr. Expt. Sta. Cir. 239, 6 pp.

Doss, B. D., Bennett, O. L., and Ashley, D. A. 1962. Evapotranspiration by irrigated corn. Agron. Jour. 54: 497-498.

Doss, B. D., Bennett, O. L., Ashley, D. A., and Weaver, H. A. 1962. Soil moisture regime effect on yield and evapotranspiration from warm season perennial forage species. Agron. Jour. 54: 239-242.

Elkins, C. B., Jr., and Williams, G. G. 1962. Still and time-lapse photography of plant stomata. Crop Sci. 2: 164-166.

Erie, Leonard J. 1962. Irrigation management for optimum cotton production. Proc. Beltwide Cotton Prod.-Mech. Conf. 64 (2): 30-32, Dallas, Texas.

Erie, Leonard J., and French, Orrin F. 1962. Safflower--water intelligently! Arizona Farmer-Ranchman 41 (7): 6.

Erie, Leonard J., French, Orrin F., and Patterson, Lloyd L. 1962. Water management on DPL. Arizona Farmer-Ranchman 41 (11): 12-13.

Grant, Walter J., and Epstein, Eliot. 1962. Physical properties and moisture relationships of some representative Maine soil types. Maine Agr. Expt. Sta. Bul. T-2, 42 pp.

Howe, O. W. 1963. Orientated corn yields less under irrigation. Crops and Soils 15 (4): 20.

Jensen, M. E., and Haise, H. R. 1962. Estimating evapotranspiration for various crops under solar radiation. Sprinkler Irrig. Assoc. Open Tech. Conf. Proc., Kansas City, Missouri, 16 pp. (Mimeo.)

Jensen, M. E., and Hildreth, R. J. 1962. Rainfall at Amarillo, Texas. Texas Agr. Expt. Sta. MP-583, 9 pp.

Jensen, M. E., and Musick, J. T. 1962. Irrigation grain sorghum. U.S. Department of Agriculture Leaflet No. 511.

Miller, D. E., and Kemper, W. D. 1962. Water Stability of aggregates of two soils as influenced by incorporations of alfalfa, Agron. Jour. 54: 494-496.

Pair, Claude H. 1962. Will irrigation pay? World Crops 14:117-120.

Robins, J. S., and Domingo, C. E. 1962. Moisture and nitrogen effects on irrigated spring wheat. Agron. Jour. 54: 135-138.

Shull, Hollis. 1962. Weed seed in irrigation water. Weeds 10 (3): 248-249.

van Bavel, C. H. M., and Harris, D. G. 1962. Evapotranspiration rates from Bermudagrass and corn at Raleigh, North Carolina. Agron. Jour. 54: 319-322.

Willhite, F. M., Lewis, R. D., and Rouse, H. K. 1962. Improving mountain meadow production in the west. U.S. Department of Agriculture, Agriculture Inform. Bul. 368, 22 pp.

Surface Irrigation Hydraulics and Water Intake

Fangmeier, D. D., and Swanson, N. P. 1962. A device for remote measurements of flow depths in shallow streams. Agr. Eng. 43 (5): 290-291.
Kruse, E. G. 1963. The hydraulics of small, rough irrigation channels. Internatl. Comm. Irrig. Drain. Proc. 5th Cong. 16: 161-176.

Sprinkler Irrigation Techniques and Water Distribution

Keller, Jack, Willardson, L. S., and Woodward, G. O. 1962. Let's take a closer look at sprinkler irrigation interval and system capacity design factors. Open Tech. Conf. Proc. Sprinkler Irrig. Assoc., Washington, D. C., pp. 56-66.

Systems Design for Efficient Use of Water and of Labor in Water Application

Dimick, N. A., Minyard, J. A., and Bush, L. F. 1963. Irrigated pastures on the Belle Fourche Project. South Dakota Farm and Home Res. 13 (4): 18-20.
Jensen, M. E. 1962. Book review: Agricultural engineers handbook, McGraw-Hill Book Co., Inc. Agron. Jour. 54: 4.
Kruse, E. G., Schleusener, P. E., Shelby, Walter E., and Somerhalder, B. R. 1962. Sprinkler and furrow irrigation efficiencies. Agr. Engin. 43: 636-639, 647.

AREA 6: DRAINAGE PRINCIPLES, REQUIREMENTS, PRACTICES, AND FACILITIES FOR PROTECTION OF CROPS AND SOILS

Problem. Water management systems have been applied to some 140,000,000 acres of potentially wet lands in the United States. Over 90,000,000 acres are in organized districts and the remainder are individual farm enterprises. The Soil Conservation Service reported in 1957 that 67,000,000 acres of cropland needed improved drainage. The U.S. Census Report for 1960 shows an expenditure during the last 10 years for new drainage work constructed, enlarged, or installed of nearly $186,000,000 and a cost of maintenance, operation, and repair of over $231,000,000.

There are numerous water management problems on these lands. High water tables during the spring restrict root development, which lowers the plants'drought resistance during the dry periods that generally follow. Imponded water in microtopographic depressions delay plantings beyond optimum dates, and makes the use of modern high-speed farming equipment uneconomical. Hillside seep areas function similarly to reduce farming efficiency in northeastern and north central dairy farming areas.

The economic success and feasibility of many irrigation projects depend upon adequate subsurface drainage to prevent salting out and abandonment of the projects. On over 50 percent of the total irrigated acreage, drainage is a necessary complement for successful operation.

USDA PROGRAM

The Division conducts both basic and applied research and development in the area of land drainage utilizing agricultural and hydraulic engineers, soil physicists, and plant physiologists. Surface drainage problems including land forming, drain depth, spacing, and conveyance for humid areas are under study in Virginia, Louisiana, and Minnesota. The application of new materials and development of installation techniques and equipment for subsurface drainage are underway in Ohio, Louisiana, Minnesota, Colorado, North Dakota, Texas, Utah, and California. Interception drainage for the control of seeps on hillsides, below impoundments, and in other special areas is being studied in Vermont, New York, Wisconsin, and Oklahoma. Drainage of irrigated and other salt-affected lands for ground water level and salinity control is under study in Colorado, North Dakota, Texas, Nevada, and California. The drainage requirements of crops is being studied in North Carolina, Florida, and Nevada. Laboratory studies of soil properties, water transmission, and drain depth and spacing, utilizing tank models and electric resistance networks, are underway in Ohio, Georgia, Utah, Minnesota, Colorado, and Texas. The performance of drainage systems including surface and subsurface systems alone and in

combinations is being studied in Ohio, New York, and Minnesota. The scientific and engineering effort in this area totals 18.2 professional man-years. Of this total 1.7 are devoted to surface drainage--land forming, drain depth, spacing, and conveyance for humid area conditions; 3.0 to subsurface drainage--new materials, techniques, equipment, and hydraulics; 2.5 to interception drainage; 3.6 to irrigation drainage and drainage for salinity control; and 7.4 to design of optimum systems for crop growth--drainage requirements of plants; soil properties, water transmission, drain depth, and spacing; and systems performance.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Surface Drainage--Land Forming, Drain Depth, Spacing, and Conveyance for Humid Area Conditions

Land forming studies to improve surface drainage in the Coastal Plains area of Virginia has shown that the practice can greatly reduce the need for open ditches on these soils. The 1962 data confirmed that of previous years that there is no significant difference in corn yields for plot widths of 200 to 400 feet, nor with increasing distance from adjacent open ditches. In the Piedmont area, corn yields on rows graded to 0.1 percent did not differ significantly with length. Yield differences between cut and fill areas have been less than 10 percent over a 3-year period and these differences were seldom significant. The data presented indicate that land forming can greatly improve drainage efficiency on level lands in both soil areas as well as being better adapted for mechanized farming. (SWC 6-a1)

The first data in a study to determine the most efficient row length and grade for surface drainage in the Mississippi Delta at Baton Rouge, Louisiana, were secured during the year. Instruments have been installed to record rates and amounts of runoff from row crop furrows of different grades and length. A device was developed to make a continuous record of evaporation to relate with the rate of drying in the soil. (SWC 6-b2)

B. Subsurface Drainage--New Materials, Techniques, Equipment, and Hydraulics

Plastic-lined mole drains with the overlap-type closure installed in 1958 in Billings clay loam at Grand Junction, Colorado, to depths ranging from 18 to 24 inches, show that the drains have retained their generally round shape and diameter of about 2 inches. However, in 1962, roots of alfalfa-brome planted in 1961 were found to be growing in some of the tile lines and were occupying as much as one-fourth of the 2-inch opening. In other cases, silt had nearly clogged the tile line. These results indicate that plastic-lined mole drains with this type closure would have limited application. Also, deeper installations are considered necessary under most western irrigation conditions for leaching to control accumulation of excess salt. (SWC 6-d1)

Continued observation of plastic mole drain liners with overlap-type closure at Crookston, Minnesota, showed that about one-half of the drains were functioning satisfactorily. Drains that functioned properly 6 months after installation appeared to be stabilized with no further reduction in size or other type of failure.

In Ohio, results show that 2 years after installation plastic-lined mole drains with the zipper-type closure are more stable than those with the overlap-type. Compaction of the soil slit after installation provided a stabilizing effect on the overlap-type, but had a slight damaging effect on the zipper-type liner.

A preliminary structural analysis of the plastic mole drain liner with zipper-type closure using the compression ring theory of flexible conduit loading, along with supporting field data and observations, indicate that, to prevent the top of the liner from moving upward under the soil load the soil immediately over the liner should be more compacted than secured with the present slit closure device. This is true for both clay and muck soils. The results of the experiment in muck soil also indicate that the soil at the sides of the mole liner did not have sufficient bearing strength to prevent the liner's sidewalls from moving outward. The theoretical calculations indicated that the zipper-type closure should not fail in compression except where the drain is very shallow and subjected to severe surface loads.

For the arch-with-floor-type plastic mole drain liners in the Ohio-Indiana studies, the unattached floor was not entirely satisfactory, as in several cases it worked up into the drain channel. In clay soils arch roof of 20-mil. plastic maintained a larger drain channel than 15-mil. plastic. In muck soil, the use of 20-mil. plastic in the arch maintained the channel shape and size, but soil still filled the drain from the bottom.

Based on present results, the overlap with "cap" plastic mole liner appears to be the best type for muck soil, since it maintains an open drain channel, although quite small, and does not completely collapse. The zipper- and arch-type liners would probably perform better in the unoxidized portion of the muck profile.

Unlined mole drains did not remain open when installed below the water table in the oxidized portion of the muck soil profile. Life of these mole drains was less than one year.

At Columbus, Ohio, preliminary field trials with the partially completed tool-bar-mounted mole plow showed that the plow design satisfied the desired performance characteristics. That is, the mole plow would "float" over a range of operating depths and the forward location of the hitch point on the tractor provided dynamic stability for the crawler tractor and eliminated backward tipping. (SWC 6-c1)

Two specialized pieces of drainage equipment were developed at Weslaco, Texas, that will contribute to low-cost, rapid installation of long lengths of drainage tubing in deep trenches. A machine to perforate flexible plastic and rigid fiber tubing utilizes slotting saws with concave faces. The perforating machine has been used successfully to slot flexible plastic tubing and will be used also for slotting rigid asphalt-impregnated fiber tubing. The trenching machine cuts a trench only 9 inches wide and lays flexible plastic tubing in 20-foot or longer lengths. (SWC 6-e2)

At Brawley, California, five different commercial fiber glass tile drain filter materials with a nominal thickness of one inch were subjected to external loads and tested for hydraulic conductivity and for their filtering characteristics. Hydraulic conductivity decreased with increased external loading and consequent reduction in mat thickness in a manner that could be expressed by a mathematical equation. A direct ratio exists between transverse and lateral hydraulic conductivity. Although the hydraulic conductivity of compressed glass fiber mats is less than that of conventional gravel filter material, it is greater than that of most soil materials and therefore adequate for use with tile drains. Preliminary results of the filtering characteristics of fiber glass mats show that it acts as an effective filter to all soil particles larger than clay. Controlled laboratory tank studies and observations of field trials over an 18-month period indicate satisfactory performance of bitumen fiber drains using fiber glass filters.

At Brawley, California, a camera was constructed that takes photographs inside subsurface tile drains to characterize the inside alignment and to check on obstructions and clogging problems. The camera is mounted inside a 3-inch-diameter cylindrical tube along with a circular flash tube and associated flash equipment. The cylinder containing this equipment is self-propelled. Controls to move the device forward and backward in the drain line, to advance film, and to flash the flash tube are located in a control console which is cable-connected to the camera cylinder. (SWC 6-g2)

C. Interception Drainage

In Vermont, instrumentation to develop and evaluate drainage practices for wet, seepy hillsides in terms of water outflow was completed in 1962. In addition, a large number of piezometers were installed to evaluate directional flow of water in the soil. Piezometric data for 1962 again indicated that the greatest flow of subsurface water occurs parallel to the soil surface. Near the diversion ditches, there is some upward flow toward the channel, but below the 3-foot depth, flow is either parallel to the surface or, to a limited extent, downward. Hydraulic conductivity measurements are being made so that an electric analog solution for drainage problems on sloping land can be made. (SWC 6-a1)

At Columbus, Ohio, the solution for the drainage of sloping land indicated that the hydraulic conductivity of the backfill has a much greater influence on drain flux than altering the drain depth.

In a study at Black Earth, Wisconsin, artesian wells reduced the piezometer heads by 0.54, 0.33, and 0.16 foot at locations 45, 90, and 190 feet from the wells. These amounts are only 9, 6, and 3 percent of the total head causing flow through the silt layer. To effect a 50-percent reduction in flow potential probably would require wells spaced 100 feet apart on both sides of the field. Under the present economic conditions, the cost of the wells would be prohibitive. Closer spacing of tile lines appears to be a much cheaper alternative. However, the cost of the artesian wells could be reduced considerably by backfilling with gravel instead of casing with tile or steel. (SWC 6-c1)

D. Irrigation Drainage and Drainage for Salinity Control

Microrelief accentuates the problem of poor drainage and accumulation of excess salts in the ridges on approximately 400,000 acres of land in the Red River Valley of North Dakota. The shallow ground water regime in the "ridge-depression" microrelief near a shelterbelt was studied to evaluate ground water movement as it influences high salinity in the ridges compared to low salinity in the depressions. Ground water movement was found to be affected by surface relief. Hydraulic conductivities of soils in the depressions were found to be greater than that in the ridges. This with impondment of precipitation resulted in more water movement, and more leaching of salts. The tree and vegetative growth in the depressions caused greater removal of ground water through evapotranspiration and general lowering of the water table in the depressions. The greater leaching of salt that occurs in depressions was reflected by the low concentration of salts in effluent from a tile line installed in the same general area. The effluent, averaging 1.8 mmhos./cm., intercepted shallow ground water from the relatively nonsaline depressions while salt content in ridges remained relatively high. (SWC 6-d1)

Investigations of drain tile systems, up to 50 years old, in the Lower Rio Grande Valley of Texas, to determine design factors that reduced the effectiveness of the systems in providing ground water level and salinity control, revealed that none were completely successful. Factors investigated included: (1) Water table drawdown; (2) sediment in tile lines; (3) type of material used for envelope or backfill around tile; (4) salinity reclamation; and (5) maintenance of outlets. Predominate causes of partial or total failures include absence of suitable envelope or blinding material, poor alignment, large cracks between tiles, and lack of outlet maintenance. (SWC 6-e2)

At Pomona, California, exploratory work continued on the solubility of manganese and iron oxides in subsoils in an effort to learn more concerning the processes by which these compounds clog tile lines in some soil areas. Tests run on soil samples from Huntley, Montana, Grand Junction, Colorado, and Brawley and Coachella, California, showed that treating the subsoil with organic matter increased the solubility of these compounds. It has also been shown that the easily reducible iron and manganese increases with depth in the profile. (SWC 6-g2)

At Brawley, California, an electrical analog for computing tile spacing was developed to solve the Donnan spacing formula. This analog is constructed so as to relate parameters in the spacing formula to resistances in a balanced wheatstone bridge circuit. The analog has the advantage of rapid manipulation and ease of operation when compared with either a nomograph or arithmetic methods. (SWC 6-g1)

E. Design of Optimum Systems for Crop Growth

1. Drainage requirements of plants. The drainage requirements of crops is one of the most important factors to be considered in designing drainage systems. In studies at Raleigh, North Carolina, the Lee Variety of soybeans grew and yielded well with the water table at 6 inches depth while the Ogden variety required 18 to 24 inches depth for best growth, suggesting that plant breeding and selection may have potential for specific set water table conditions. Raising the water table from 18 to 12 inches or from 12 to 6 inches at flowering stage of Lee soybeans caused an increase in plant growth and seed yield. Corn responded to improved aeration as the water table was lowered in the soil to 34 inches depth, but yields declined from a lack of soil moisture in the root zone when the water table was below 34 inches. An average rate of oxygen diffusion in excess of 15×10^{-8} gm./cm^2/min. was required for maximum corn yields. The yields of kidney beans were the same at water table depths of 6, 12, 18, 24, 30, and 36 inches in a climate-controlled chamber where the ambient day and night temperatures were 85° and 70° F. The water use rates, however, ranged from 0.378 inch per day for the water table at 6 inches to 0.076 inch per day for the water table at 36 inches.

An equation was developed for predicting the spacing of tile drains based on the rate of drawdown of the water table desired to meet the drainage requirements of the crops. A flow meter was developed in the laboratory to measure very low rates of water flow to determine the unsaturated conductivity of soils.

Average daily rates of moisture use by Tifway Bermudagrass at Fort Lauderdale, Florida, were 0.176, 0.170, and 0.164 inch in May and 0.070, 0.066, and 0.058 inch in December from water table depths of 12, 24, and 36 inches, respectively. There was significant protection in the grass from frost damage with the 12-inch water table when the above-ground air temperature reached 25° F. in December. (SWC 6-b1)

2. Soil properties, water transmission, and subsurface drain depth and spacing. At Fleming, Georgia, the physical properties of soils that affect the drainage characteristics and the efficient design of drainage systems were determined for 11 soil series taken from 19 sites in Georgia and South Carolina. The surface soil textures from the different sites ranged from Ona sand with 93, 5, and 2 percent sand, silt, and clay to Bladen fine sandy loam with 29, 46, and 25 percent sand, silt, and clay.

Moisture release curves showed that the available water capacity in the top 36 inches of the soil profile ranged from 0.44 inch for the Ona sand to 7.92 inches for the Bladen series. There was little difference in pH of these soils when sampled wet and after air drying, indicating no susceptibility to increased acidity after draining these Atlantic Coast soils. (SWC 6-b2)

At Riverside, California, an evaporimeter method has been developed which gives a direct measure of the water moving up through the soil from the water table, and can also be used to measure evapotranspiration. Specific attention has been given to the problem of measuring evaporation losses because such evaporation contributes to soil salinization and because of the direct loss of valuable ground water. Although the evaporimeter is difficult to install, the method produces good results for time intervals as short as one week. The salt accumulation method has been shown to give usable but less precise estimates of flow rate. Also, longer time intervals must be used than are necessary for the evaporimeter method. (SWC 6-gF1)

At Tempe, Arizona, a simplified method has been developed for predicting the fall of the water table in drained land. Steady-state drainage solutions relating drainage rate to water table height are integrated to predict the rate of recession of the water table.

At Logan, Utah, research was undertaken to set statistical limits for the number of hydraulic conductivity samples needed in a given area. Quantitative values for hydraulic conductivity are used in the computation of drain spacing. Using field data from 2 locations, it was possible to compute the mean and standard deviation of the permeability for each location. The equations for computing the statistical limits were solved on the IBM 1620 Computer. The statistical limits decreased as the average permeability decreased and as the number of samples increased. (SWC 6-g1)

Drainage analog studies at Weslaco, Texas, showed that in stratified soils it is necessary to measure hydraulic conductivity of each of the major strata to correctly design a drainage system. It is a common field practice to measure the integrated hydraulic conductivity for the entire profile to the depth of tile line installation. Other studies showed that movement of water to a drain can be of considerable magnitude in strata occurring at depths much greater than the drain depth, especially in the case of a soil with a very permeable substratum. The depth or stratum of greatest horizontal flow was generally found to be the optimum depth for placing a tile to obtain good soil drainage. (SWC 6-e1).

3. Systems performance. At Castalia, Ohio, the corn yields showed a significant difference between no drainage treatment and the combination of all the drainage treatments (tile, surface, and tile plus surface drainage). Significant differences in yields did not exist among the tile, surface, and tile plus surface drainage treatments. There was more yield variation among fields in the experiment than among the various combinations of tile depth and spacing. (SWC 6-c1)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Surface Drainage--Land Forming, Drain Depth, Spacing, and Conveyance for Humid Area Conditions

Hermsmeier, L. F., and Larson, C. L. 1962. Land forming--grade and row length studies in Red River Valley. Trans. Amer. Soc. Agr. Eng. 5 (2): 172-174, 179.

Saveson, I. L. 1963. An efficient drainage system for sugarcane. U. S. Department of Agriculture, ARS 41-72, 12 pp.

Subsurface Drainage--New Materials, Techniques, Equipment, and Hydraulics

Fouss, J. L., and Donnan, W. W. Plastic-lined mole drains. 1962. Agr. Eng. 43 (9): 512-515.

Interception Drainage

None

Irrigation Drainage and Drainage for Salinity Control

Gardner, W. R., and Hillel, D. I. 1962. The relation of external evaporative conditions to the drying of soils. Jour. Geophys. Res. 67: 4319-4325.

Gardner, W. R., and Miklich, F. J. 1962. Unsaturated conductivity and diffusivity measurements by a constant flux method. Soil Sci. 93: 271-274.

Design of Optimum Systems for Crop Growth

Brooks, R. H. 1962. Closing discussion: Unsteady flow of ground water into drain tile. Amer. Soc. Civil Eng., Jour. Irrig. and Drain. Div. 88 (IR-2): 95-96.

Thiel, T. J., Vimoke, B. S., and Taylor, G. S. 1963. Instrumentation and fabrication of an electrical resistance network for studying moisture flow problems. Jour. Agr. Eng. Res. (British) 8: 325-329.

van Schilfgaarde, Jan. 1962. Soil water in irrigation and drainage. Proc. North Carolina Soil Sci. Soc. 5: 82-89 (Mimeo.).

Vimoke, B. S., and Taylor, G. S. 1962. Simulating water flow in soil with an electrical resistance network. U. S. Department of Agriculture, ARS-41-65.

Williamson, R. E. 1963. The effect of a transpiration-suppressant on tobacco leaf temperature. Proc. Soil Sci. Soc. Amer., Notes 27: 106.

AREA 7: SALINE, SODIC, AND RELATED SOILS PROBLEMS, AND QUALITY OF IRRIGATION WATERS AND THEIR RELATION TO PLANT GROWTH PROCESSES

Problem. Salinity is a major problem in irrigated agriculture. In the arid West injurious concentrations of salts in the soil have impaired the use of 25 percent of the irrigated land. Fifty percent of this area is endangered.

These salts move upward in the soil with soil water to supply evapotranspiration requirements and are left behind as the moisture passes to the atmosphere. This results in injurious accumulations in the root zone unless excess water is periodically passed downward to leach the salts to the ground water or to a tile drainage system for removal in the tile effluent. When irrigation water contains a high level of dissolved salts, the problem is intensified. The nature of the salts, soil, and climatic conditions and leaching water quality create complicated problems, many of which have not been solved. The use of salt-tolerant plants offers relief, but these plants must be identified and developed.

To live with salinity, to control it, and to reclaim salty soils, research must develop fundamental theories and principles of the relations of saline irrigation waters and salt-affected soils to the plant growth processes. The next problem is to develop application techniques for use of these principles in diagnosis and improvement of saline and sodic soils and waters in specific field situations.

USDA PROGRAM

The Division conducts both basic and applied research in the area of saline and sodic soils and quality of irrigation water for the growth and production of agricultural crops and ornamental plants. Scientists involved in this research include physicists, chemists, soil scientists, plant physiologists, agronomists, and agricultural engineers. The center for basic research in this area is the U. S. Salinity Laboratory, Riverside, California. Studies deal with mechanisms of reaction important in salt-affected soil and water, and diagnostic techniques; physiological basis for tolerance of plants, and adaptation and response of plants to salt-affected soil and water; water composition, salt balance, and reactions occurring when salt-affected soils are irrigated and drained; and leaching of salts by rainfall and overirrigation. AID projects in operation at the Laboratory are: (1) Salt and boron tolerance of plants of special importance to AID missions; and (2) interpretation and adaptation of diagnostic techniques for AID use.

Brackish water studies for the Atlantic Coast flatwood resource areas are centered at Norfolk, Virginia, with supporting work in New Jersey and Georgia. Salinity problems of the Rio Grande Plain and Lower Valley areas are under study at Weslaco, Texas, and those of the Red River Valley at Grande Forks, North Dakota. Crop and soil management systems and leaching studies for saline and sodic soils are underway in North Dakota, Colorado, Texas, California, Oregon, Montana, and Virginia. The scientific and engineering effort in this area totals 25.3 professional man-years per year, two-thirds of which is at the U. S. Salinity Laboratory. Of the total professional man-years, 7.4 are devoted to mechanisms of reactions of importance in salt-affected soil and water and diagnostic techniques; 10.4 to physiological basis for tolerance of plants, and adaptation and response of plants to salt-affected soil and water; 1.7 to water composition, salt balance, and reactions occurring when salt-affected soils are irrigated and drained; 3.3 to crop and soil management systems for various levels of salinity and sodium saturation of soils; and 2.5 to leaching of salts by rainfall and overirrigation.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Mechanisms of Reactions of Importance in Salt-Affected Soil and Water and Diagnostic Techniques

1. Adsorption of sodium by soils. In evaluating the suitability of waters for irrigation, an important consideration is the extent to which soils will adsorb sodium from the water by cation exchange. The exchangeable-sodium-percentage (ESP) of soils is directly related to the sodium-adsorption-ratio (SAR) of the soil solution. Hence, if, with continued irrigation, a steady-state condition is attained in which the SAR of the soil solution becomes equal to or closely related to the SAR of the irrigation water, then the latter is a useful index of irrigation-water quality.

Concentration of the soil solution by evapotranspiration and solution of cations from soil minerals are processes which may be expected to influence the steady-state relation between the SAR value of the irrigation water and that of the soil solution. In studies of these influences at the U. S. Salinity Laboratory, the steady-state SAR values of the soil solution from cropped pots exceeded the SAR values of the irrigation waters, and, in general, were about twice those from noncropped pots. With removal of 25 percent of the water applied to cropped pots as leachate, the total cation concentration of the soil solution increased to a value about four times that of the applied water between irrigations. Inasmuch as the SAR of a solution increases upon concentration (loss of water) in proportion to the square root of its total cation concentration, steady-state SAR values for the cropped pots should logically be approximately twice those from noncropped pots.

The solution of cations from soil minerals had an important effect in preventing the steady-state SAR values under noncropping conditions from becoming equal to the values for the applied irrigation waters. Even though evaporation from noncropped pots was essentially prevented by the use of polyethylene film, the total cation concentrations of the drainage waters exceeded those of the irrigation waters by 3.6 to 9.0 meq./l. Because calcium was released from minerals in greater quantities and was more strongly adsorbed by the exchange complex than sodium, the steady-state SAR values of the drainage water were, for the most part, considerably less than those of the irrigation waters. (SWC 7-gF1)

Laboratory studies at Norfolk, Virginia, on ion exchange reactions at different levels of base saturation involving saline solutions, indicated the importance of considering the charge characteristics of the soil with regard to the pH-dependency. Treating the soil with a solution containing 60 meq./l. of NaCl and 16 meq./l. of $CaCl_2$ (SAR 21.2) resulted in the adsorption of Ca by the most acid soils and desorption as soil pH increased. The amount of sodium adsorbed from this solution by the soil increased with increasing base saturation, but the ratio of Na_{ads}/Ca_{ads} decreased. Ratios obtained for different soils were comparable. (SWC 7-a1)

2. Determination of the sodium status of soils. The exchangeable-sodium-percentage (ESP) has long been used to indicate the sodium status or hazard of salt-affected soils. When ESP is determined by conventional laboratory methods, much time is required and appreciable errors may occur. This is due to the indirect nature of its determination, as indicated by the formula:

ESP = (Total sodium - soluble sodium) X 100/CEC.

Previous research at the U. S. Salinity Laboratory, based on a limited sampling of United States' soils, demonstrated that the sodium-adsorption-ratio (SAR) serves to predict the ESP status of the soil. The SAR formula is unique in that it takes into consideration changes in both the concentration and the composition of salts present in the soil solution. This study was recently extended to 218 soil samples from the United States and 23 foreign countries, and the data verify to a remarkable degree the usefulness of the SAR for predicting the ESP of soils. Thus, SAR can be used with confidence in all arid countries of the world to determine the sodium status of salt-affected soils. Its use eliminates the time-consuming determinations of total sodium, soluble sodium, and cation-exchange-capacity (CEC) which are required for measuring ESP directly. (SWC AID-0-1-4)

3. Soil structure in relation to mineralogical composition. At the U. S. Salinity Laboratory, data for 10 soils revealed rather marked effects of mineral composition on the hydraulic conductivities (HC) of soil columns.

Though soil texture and structure exerted a dominant effect on the absolute HC values for most soils, the mineralogy of the clay fraction largely determined the resistance of the soil to decrease in HC with decrease in salt content or increase in the proportion of sodium in the percolating solution. In general, soils with amorphous or crypto-crystalline components exhibited the most stable structure under high sodium-low salt regimes, and soils high in montmorillonite exhibited the most labile structure; micaceous soils were intermediate in their behavior. Preliminary calculations indicated that only in the high montmorillonite soils could in situ swelling account for the decreases in HC accompanying use of high sodium-low salt irrigation waters. Decreases in the HC of soils dominated by micaceous and amorphous minerals were more probably caused by dispersion and translocation of particles, with a resultant plugging of conducting voids. This hypothesis was supported by measurements of the reversibility of such decreases. (SWC 7-gF2)

4. Surface area of soils and clay minerals. By using a combination of thermal and gravimetric methods it has been shown at the U. S. Salinity Laboratory that considerable glycol retention is associated with the exchangeable calcium of clays and soils. Glycol retention by crystalline soil clays normally includes 2 glycol molecules associated with each exchangeable calcium ion present. Errors of 25-40 percent in surface charge density measurements can be obtained if the species of exchangeable cation are not rigorously controlled. Use of high-temperature glycol desorption as a more rapid technique for measuring surface area was found to be hazardous because of the enhanced differences in retention between minerals of varying exchangeable cation composition and because of the difficulties in adequately maintaining suitable partial pressures of glycol in the system. Development of a surface area technique dependent solely upon the extent of available surface in the sample is currently being attempted. (SWC 7-gF3)

5. Biological reduction of sulfates. The conditions for reduction of sulfate to sulfide include the presence of the sulfate-reducing organism, an anaerobic environment, a source of organic energy material, and a supply of sulfate salts. Such conditions may occur in poorly drained saline soils. Studies at the U. S. Salinity Laboratory warrant the following conclusions regarding sulfate reduction after submergency of field soils containing up to 8 meq. of sulfate per 100 gm. of soil for periods up to 275 days. The reduction will probably be negligible in mineral soils unless amended with undecomposed plant residues. When plant residues, such as straw, are added at the rate of 1 percent, as much as 8 meq. of sulfate per 100 gm. of soil can be reduced. Such reduction will be indicated by a darkening of the soil, due to precipitation of heavy metal sulfides, and the odor of hydrogen sulfide. Concomitant with sulfate reduction, a decrease in soil salinity occurs. For Chino clay, the decrease in salinity was about 0.38 meq. of salt for each milliequivalent of sulfate reduced. Associated

with the decrease in salinity, there is an increase in the sodium-adsorption-ratio and the exchangeable-sodium-percentage of the soil. Sulfate reduction will be much more prevalent in organic soils than in mineral soils owing to the higher cellulosic content of the former. (SWC 7-gF2)

Studies at Weslaco, Texas, show that clay content increases with depth in all soils of the area, but in saline soils the increase is greater. Clay contents of the surface 3 inches and the fifth foot average 25.1 and 32.4 percent, respectively, for productive soils, compared with 22.9 and 44.9 percent, respectively, for saline soils. The cation exchange capacity does not change with depth in productive soils of the area, whereas it increases with depth in saline soils. The saline soils are sodium affected throughout the profile, but productive soils are sodium affected only below a depth of 4 feet. Grain sorghum yields in the nonirrigated area were inversely proportional to salt concentrations. The 50-percent yield reduction point varied between EC_e values and 7.0 and 12.0.

Photogrammetry and spectrophotometer studies were used at Weslaco, Texas, to determine the severity and extent of salinity in the dryland, cotton-producing area. Cotton was found to be a good indicator of the degree of salinity to a depth of 4 feet. Six levels of salinity in the profile could be detected by studying tone contrasts on aerial photographs. (SWC 7-e1)

B. Physiological Basis for Tolerance of Plants, and Adaptation and Response of Plants to Salt-Affected Soil and Water.

1. Uptake of water by plants. The mathematical theory for the uptake of water by plants developed at the U. S. Salinity Laboratory is based upon the assumption that the rate of water uptake by a plant is proportional to the difference between the total soil suction and the plant suction. The resulting equations relate water availability to both soil and atmospheric factors. In a series of greenhouse experiments, agreement between the observed and the predicted behavior of the plant-soil-water systems was very good. In the systems studied, root distribution with depth was of major importance in determining water uptake, with the water retention and transmission properties of the soil next in importance. Transpiration by bell pepper, birdsfoot trefoil, sunflower, and cotton was measured as a function of the suction, or diffusion-pressure-deficit (DPD), and the relative-water-content (RWC) of the leaves. (SWC 7-gF4)

2. Osmotic adjustment of plants to saline media. Studies at the U. S. Salinity Laboratory emphasized the importance of specie and organ specificities in the increased accumulation of cations under saline conditions. Although potassium contributed importantly to the immediate osmotic adjustment following an increase in salinity, other cations replaced potassium more or less rapidly in this function. The cations present in high concentrations in the medium contributed to this secondary adjustment

only if these cations were readily accumulated by the organ in question. Over extended periods of culture, chloride concentration regularly exceeded the increased concentration of soluble cations, but in short-term period, the reverse was true. The immediate cationic absorption following salination would appear to be accompanied by increased organic acid content. (SWC 7-gF6)

3. Soil matric suction and plant leaf extension. In studies at the U. S. Salinity Laboratory to determine the effect of high soil matric suction on cell division and cell elongation in sunflower leaves, the leaf extension decreased with increase in the soil matric suction above a certain value and eventually ceased when the leaf became permanently wilted. The decreased leaf extension appeared to be primarily from limited cell elongation since cell counts indicated continued nuclear division. The rapid rate of leaf extension following restoration of a very low soil matric suction also appeared to be related to cell elongation. (SWC 7-gF6)

4. Salinity and metabolism. From studies at the U. S. Salinity Laboratory, it was concluded that salinity suppressed leaf development by inhibiting cell division, without necessarily inhibiting cell enlargement. The division of cells is contingent on the preliminary synthesis of RNA, protein, and DNA, in that order. Green leaves, unlike nonphotosynthetic tissue, require light in order to carry out these processes. Studies with isolated leaf tissue have shown that salt modifies the utilization of light energy, apparently by directly affecting the photosynthetic apparatus. At light intensities below 400 foot candles NaCl appreciably stimulates the synthesis of RNA and protein, but has no apparent effect on the synthesis of DNA. At 1,000 foot candles, NaCl strongly suppresses the synthesis of all three, and in addition causes some loss of chlorophyll. Photooxidation of chlorophyll is a common occurrence in plants growing in the open, but usually only at light intensities much higher than 1,000 foot candles. NaCl appears to potentiate this reaction at unusually low light intensities. The leaf burn associated with chloride injury in some species is probably a related phenomenon. (SWC 7-gF7)

5. Absorption and translocation of sodium by plants. Although a common constituent in the solution phase of saline soils, sodium is not absorbed and translocated with equal facility by all species of plants growing on such soils. Studies at the U. S. Salinity Laboratory show very little, if any, of the sodium absorbed by the roots of bean plants is translocated to the stem, petioles, and blades. Cotton, on the other hand, translocates appreciable amounts of sodium to the stems, petioles, and blades.

The studies indicate that the absorption of sodium by bean and cotton roots requires energy. Once the sodium has been absorbed by bean roots, its movement is regulated by membranes in the roots and stem. By contrast, sodium readily enters the vascular tissue of cotton plants, and its movement is regulated by the transpirational stream. (SWC 7-gF7)

6. Salt tolerance of crops. Safflower, an important oil-bearing seed crop in many arid countries of the world and also in the western United States, was found to be highly salt tolerant. In studies at the U. S. Salinity Laboratory, maximum yields averaged about 4,000 pounds of seed per acre on the control plots, and only moderate reductions in yield were noted at high salinity levels. For example, at EC_e = 11 mmhos./cm., a 20 to 25 percent decrease in yield occurred. Accordingly, a yield decrease of 50 percent would be expected to occur at 14 or 15 mmhos./cm. Thus, safflower appears to be only slightly less salt tolerant than cotton. Both flowering and maturity were accelerated by salinity, with the greatest effect on maturity. On the high-salt plot, plants flowered only 3 days earlier, but they matured and were harvested 3 weeks earlier than on the control plot. Laboratory germination tests indicate that increasing salinity delayed germination and decreased the ultimate germination percentage. Emergence time was doubled at a salinity level of about 7.0 mmhos./cm., which indicates that safflower appears to be only half as tolerant to salinity during germination as it is at later stages of development. (SWC 7-gF5 and SWC AID-0-1-2)

A 3-year study of 4 varieties of bermudagrass, vegetatively propagated, indicated that Coastal and Suwanee varieties are considerably more salt tolerant than Greenfield and Common varieties. The former 2 varieties gave a 50-percent decrease in yield at a high salinity level of 23 mmhos./cm., whereas the latter 2 varieties gave the yield decreases at 18 mmhos./cm. Evidence from this study indicates that the higher salt tolerance of some varieties may be related to their mineral composition. Suwanee and Coastal varieties accumulate less sodium, exhibit lower calcium levels, and maintain higher potassium levels than the less tolerant Greenfield and Common varieties. The maintenance of higher potassium levels on the saline treatments associated with limited Ca and Na uptakes may be of real significance in making the Coastal and Suwanee varieties more salt tolerant than the other two. In a subsequent experiment, the salt tolerance of a new seed-producing variety, NK 37, was found to be comparable to that of Common and Greenfield bermudagrass and considerably less than that of Coastal and Suwanee. (SWC AID-0-1-2)

In a study of salt tolerance of ornamental shrubs at the U. S. Salinity Laboratory using sand cultures, definitive allocation of salt injury effects to specific ion toxicity was possible. Without notable exception, all 12 species studied developed characteristic leaf burn or bronzing symptoms when leaves accumulated about 1 percent chloride or sodium on a dry-weight basis. The shrubs evidenced the same response to those ions as do most fruit trees, vines, and berry bushes, as well as many forest and shade trees. This sensitivity appears to be characteristics of woody, perennial plants in contrast to annual and herbaceous, perennial plants. In field plot studies under normal growing conditions, the more tolerant oleander and bottlebrush grew satisfactorily at salinities up to 10 mmhos./cm., but

the sensitive rose and guava failed at salinities only one-fourth as great. These data will be used in diagnosing salt injury and in recommending suitably tolerant shrubs for salt-affected areas. (SWC 7-gF8)

7. Tolerance of plants to boron. Crop injury caused by excess boron in the soil solution occurs more frequently and is more widespread geographically than generally realized. Research at the U. S. Salinity Laboratory has shown that the boron concentration in the solution of a given soil remains reasonably constant over a wide moisture range, and that plants respond to the boron dissolved in the soil solution rather than to the boron adsorbed by the soil particles. This indicates that plant response, including injury, should be similar for the same dissolved boron concentration whether the plants are grown in water culture, sand culture, or in soil. (SWC 7-gF8 and SWC AID-0-1-2)

8. Brackish water studies in the humid region. A greenhouse study at Norfolk, Virginia, on the interactive effects of soil salinity, nitrogen (N), and phosphate (P) fertilization on a P-deficient Bladen silt loam indicated that increasing rates of N fertilization had no effect on vegetative yields of beans but decreased the yield of pods. Yields decreased with increasing salinity, with no interactive effects of N. Increasing rates of P fertilization increased yields of both pods and vines. Although yields decreased with increasing salinity, at the highest saline level the yield of pods fertilized at the highest rate of P was more than double that of the unfertilized treatment. Rates of evapotranspiration decreased with increasing salinity for both the N and P series, but within the P series, evapotranspiration decreased with increasing rate of P fertilization. In another study, in which tomatoes were grown in a nutrient solution to which increasing concentrations of sea water were added, the conductivity of the cell sap and the gradient from the roots to the leaves were both shown to increase with increasing salinity. When the cell sap was analyzed for Ca, Mg, Na, and K, the sum of these cations did not show this gradient, although the cation content of the stems was generally higher than that of the roots or leaves. (SWC 7-a1)

Studies at Fleming, Georgia, with spring-planted snap beans showed that irrigation with salt-free water gave a 63-percent increase in yield, but as the salt concentration was increased the yield declined. A 1-inch irrigation with water having 4 mmhos./cm. electric conductivity caused a reduction in yield of 53 percent, and a 2-inch irrigation, a reduction of 74 percent, as compared with no irrigation. Summer rains removed the salt from the soil root zone, and fall-grown turnips, collards, and kale were not affected by the salt water applied to the snap beans. (SWC 7-b1)

C. Water Composition, Salt Balance, and Reactions Occurring when Salt-Affected Soils are Irrigated and Drained

Salt-balance studies. The term "salt balance" is used to indicate

the relation between the quantity of dissolved salts brought to an irrigation project in the irrigation water, and the quantity of dissolved salts removed from the project in the drainage water.

Field studies conducted on the Rio Grande project in New Mexico and Texas by the U. S. Salinity Laboratory, in cooperation with the U. S. Bureau of Reclamation, the United States Section of the International Boundary and Water Commission, and the U. S. Geological Survey showed unfavorable salt-balance conditions in all 3 divisions of the Rio Grande project during the drought years of the last decade. Favorable salt-balance conditions have now been restored in the upper division, but unfavorable conditions still persist in the 2 lower divisions of the project. The studies reveal that salt-balance observations reliably indicate the trend of salinity conditions on an irrigation project. Several consecutive years of unfavorable salt-balance conditions are usually accompanied by more or less general salinity problems on the project lands. Similarly, several consecutive years of favorable salt balance indicate that reclamation is taking place and that conditions are improving. (SWC 7-gF10)

D. Crop and Soil Management Systems for Various Levels of Salinity and Sodium Saturation of Soils.

Studies of salinity and salt removal in the Red River Valley of North Dakota showed that the conventional practice of clean summer-fallowing preceding sugar beets reduces salinity in the soil even though the saline ground water table is within 3 feet of the surface during part of the season, whereas cropping to grass or barley has little effect on salt status of the soil.

Large areas of central North Dakota contain small patches of both unproductive and degraded solonetz soils. Preliminary results indicate that deep tillage to break up the claypan improves grass yields and that deep tillage combined with application of gypsum and manure reduces adsorbed sodium significantly. (SWC 7-d1)

At Weslaco, Texas, saline soil reclamation studies showed that soluble salts were leached downward in the soil profile of undercut plots receiving runoff from a contributing area. The depth of leaching was related to the quantity of runoff received and the initial salt concentration. Combining mulching with water application by sprinkling resulted in a greater leaching efficiency than did sprinkling or flooding without mulching. (SWC 7-e1)

Low-producing, saline-sodic, "slick spot" soils in southwestern Idaho and southeastern Oregon represent substantial portions of many irrigated fields. Studies initiated in 1957 using small plots indicated that mixing the profile would increase intake rates and reclaim the affected area.

Deep plowing on a field basis was initiated in 1959 on a trial basis to achieve the desired mixing. Initial results showed increased infiltration, water and root penetration, and a four- to fivefold increase in yields. On plowed soils during the third crop year, alfalfa generally yielded five to six times that on the unplowed plots. Gypsum alone did not increase yields during the first year, but during the third year, increased yields about threefold. However, gypsum with deep plowing did not increase yields over deep plowing alone. Deep plowing alone and regular irrigation essentially reclaimed these soils in 3 crop years. The "slick spots" are small and scattered throughout the field which necessitates plowing the entire field at a cost of $30 to $50 per acre. This investment is generally returned through increased yields within 2 or 3 years. Deep plowing has not adversely affected yields on the normal soils and is rapidly being accepted by farmers in the area as a corrective measure for a serious problem that has persisted for many years. (SWC 7-f1)

E. Leaching of Salts by Rainfall and Overirrigation

Effect of water quality on soil permeability. It has been demonstrated that for a sodic soil, where the water is in chemical equilibrium with the soil, the permeability increases as the salt concentration of the water increases. Recent research at the U. S. Salinity Laboratory has shown that soil permeability continues to increase with increasing salt concentrations as high as 6,000 meq./l. At low concentrations, soil permeability becomes essentially zero. For a given salt concentration of the water, the higher the exchangeable-sodium-percentage of the soil, the lower will be the soil permeability. The amount and composition of the clay fraction of the soil is also an important variable involved in the permeability relationship. In general, the greater the amount of swelling-type clays in the soil, the greater will be the effect of exchangeable sodium and salt concentration on soil permeability. (SWC 7-gF11)

At Huntley, Montana, the saline water-dilution method, developed at the U. S. Salinity Laboratory for reclaiming saline-alkali soils, was investigated using calcium chloride as the salt source since no low quality water was available at Huntley. In 1961 only 37 inches of river water could be put through the profile in 57 days, but 146 inches could be infiltrated in the same period if water containing calcium chloride to give an electrical conductivity of 40 mmhos./cm. was used initially and the concentration gradually decreased with time. Chemical studies of the soil in 1962 showed that the calcium chloride treatment removed essentially all salts and sodium to a depth of 5 feet, but that leaching with river water reduced the exchangeable sodium in the surface 6 inches by only half; in the 6- to 12-inch depth by less than a fourth; and in the 12- to 18-inch depth only slightly. Barley yields in 1962 on the untreated soil were 14 bushels an acre; on the river water-leached soil, 20 bushels; and on the calcium chloride-leached plots, 86 bushels. Leaching with calcium chloride is too expensive for such use, but the principle that high salt

content waters can be used to maintain high infiltration rates during leaching has been verified for a natural fine-textured soil. (SWC 7-d1)

At Norfolk, Virginia, leaching a Bladen silt loam soil with distilled water after salinizing with a NaCl solution resulted in a loss of from 0.3 to 5.6 percent of the total organic matter as determined by analysis of the leaching effluents. The amount of organic matter removed increased with increasing concentration of NaCl solution and with increasing base saturation of the soil. When $CaCl_2$ solutions were used to salinize the soil, the amounts of organic matter removed were much less, but increased with increasing base saturation. There was little effect of increasing the concentration of the $CaCl_2$ solution. Leaching with a NaCl + $CaCl_2$ mixture gave results intermediate between the two single solutions. This suggests the need for improved methods of organic matter maintenance when these soils are leached by rainfall after becoming salinized from irrigation with brackish water. (SWC 7-a1)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Mechanisms of Reactions of Importance in Salt-Affected Soil and Water and Diagnostic Techniques

Bower, C. A. 1963. Adsorption of o-phenanthroline by clay minerals and soils. Soil Sci. 95: 192-195.

Bower, C. A., and Hatcher, J. T. 1962. Characterization of salt-affected soils with respect to sodium. Soil Sci. 93: 275-280.

Carter, David L. 1962. A bibliography of publications in the field of saline and sodic soils (through 1961). U. S. Department of Agriculture, ARS 41-80, 47 pp.

Hatcher, John T., Blair, G. Y., and Bower, C. A. 1962. Adjusting soil solutions to specified boron concentrations. Soil Sci. 94: 55-57.

Physiological Basis for Tolerance of Plants, and Adaptation and Response of Plants to Salt-Affected Soil and Water

Batchelder, A. R., Lunin, J., and Gallatin, M. H. 1963. Saline irrigation of several vegetable crops at different growth stages. II. Effect on cation composition of crops and soils. Agron. Jour. 55: 111-114.

Bernstein, Leon. 1962. Salt-affected soils and plants. UNESCO Paris Symposium Proc. Arid Zone Res. XVIII: 139-174.

Bernstein, Leon. 1962. Salt tolerance of plants and the potential use of saline waters for irrigation. Proc. Desalination Res. Conf., Nat. Acad. Sci., Woods Hole, Mass., pp. 273-283.

Carter, David L. 1962. A bibliography of publications in the field of saline and sodic soils (through 1961). U. S. Department of Agriculture, ARS 41-80, 47 pp.

Carter, David L., and Peterson, H. B. 1962. Sodic tolerance of tall wheatgrass. Agron. Jour. 54: 382-384.

Ehlig, C. F. 1962. Measurement of energy status of water in plants with a thermocouple psychrometer. Plant Physiol. 37: 288-290.

Ehlig, C. F., and Gardner, W. R. 1962. Movement of water to plant roots. Crops and Soils 14 (9): 24-25.

Gardner, W. R., and Ehlig, C. F. 1962. Impedance to water movement in soil and plant. Science 138: 522-523.

Gardner, W. R., and Ehlig, C. F. 1962. Some observations on the movement of water to plant roots. Agron. Jour. 54: 453-456.

Lagerwerff, J. V., and Eagle, H. E. 1962. Transpiration related to ion uptake by beans from saline substrates. Soil Sci. 93: 420-430.

Lunin, J., Gallatin, M. H., and Batchelder, A. R. 1963. Saline irrigation of several vegetable crops at different growth stages. I. Effect on yields. Agron. Jour. 55: 107-111.

Nieman, Richard N. 1962. Some effects of sodium chloride on growth, photosynthesis, and respiration of twelve crop plants. Bot. Gaz. 123: 279-285.

Nieman, R. H., and Poulsen, L. L. 1963. Spectrophotometric estimation of nucleic acid of plant leaves. Plant Physiol. 38: 31-35.

Water Composition, Salt Balance, and Reactions Occurring when Salt-Affected Soils are Irrigated and Drained

Bernstein, Leon. 1962. Salt tolerance of plants and the potential use of saline water for irrigation. Proc. Desalination Res. Conf., Nat. Acad. Sci., Woods Hole, Mass., pp. 273-283.

Carter, David L. 1962. A bibliography of publications in the field of saline and sodic soils (through 1961). U. S. Department of Agriculture, ARS 41-80, 47 pp.

Gallatin, M. H., Lunin, J., and Batchelder, A. R. 1962. Brackish water sources for irrigation along the eastern seaboard of the United States. U. S. Department of Agriculture, Prod. Res. Rpt. No. 61, 28 pp.

Grass, Luther B., Aronovici, V. S., and Muckel, Dean C. 1962. Some chemical characteristics of submerged and reclaimed sediments of San Francisco Bay system. Proc. Soil Sci. Soc. Amer. Proc. 26 (5): 453-455.

Wilcox, L. V. 1962. Salinity caused by irrigation. Jour. Amer. Water Works Assoc. 54 (2): 217-222.

Crop and Soil Management Systems for Various Levels of Salinity and Sodium Saturation of Soils

Carter, David L. 1962. A bibliography of publications in the field of saline and sodic soils (through 1961). U. S. Department of Agriculture, ARS 41-80, 47 pp.

Fanning, Carl D. 1962. Distribution of soluble salts in a typical salt spot of the Lower Rio Grande Valley. Jour. Rio Grande Valley Horticultural Soc. 16: 105-111.

Leaching of Salts by Rainfall and Overirrigation

Carter, David L. 1962. A bibliography of publications in the field of saline and sodic soils (through 1961). U. S. Department of Agriculture, ARS 41-80, 47 pp.

AREA 8: WATER AND WIND EROSION CONTROL PRINCIPLES, PRACTICES, SYSTEMS AND PREDICTION METHODS

Problem. Erosion from farm fields in the humid and semiarid areas is the major source of silt which pollutes the streams of these areas. Control of erosion is a major requirement of watershed protection and development programs.

Water and/or wind erosion control continues to be a problem in all areas having cropping systems that require periodic plowing, tilling, and planting. In both irrigated and dryland farming areas, wind erosion is a problem. Careless irrigation techniques result in erosion from irrigation water application. The Kerr Report No. 28 emphasizes that full understanding of fundamental erosion and sedimentation processes is a prerequisite for the planning and execution of successful programs for water resource development and utilization.

As new farming practices come into use, erosion and erosion control methods must be made compatible with the new farming systems for successful use of the Nation's farmlands. The wide variations possible under factors of soil, climate, crops, and management create highly complex relationships and make it imperative to determine basic principles governing the movement and loss of soil and water. Improved control measures and prediction equations developed from these principles will provide a scientific basis for application of control practices and structures and for classification of areas of potential damage for deciding land use recommendations and the retirement of critical areas to permanent vegetation.

USDA PROGRAM

The Division conducts both basic and applied research and development in the area of water and wind erosion utilizing soil physicists, soil scientists, analytical statisticians, and agricultural engineers. Basic principles and mechanics of water erosion are under study in New Hampshire, Georgia, Indiana, Minnesota, Illinois, Kansas, and Washington, and of wind erosion in Kansas. Study of soil physical and chemical characteristics in relation to water erodibility are underway in Maine, Georgia, Indiana, and Iowa. Studies to determine interrelations between climate, soil, topography, cover, and management to runoff and erosion are underway in New York, Maine, Georgia, Mississippi, Indiana, Missouri, Iowa, Minnesota, Wisconsin, South Dakota, Nebraska, Oklahoma, Texas, Oregon, and Washington, and to wind erosion in Kansas, Texas, and Idaho. Studies to develop improved water erosion prediction methods are underway in Indiana and Mississippi, and for wind erosion in Kansas. The development of practices, structures, and

systems for modification of wind, water, and soil movement is underway in New Hampshire, New York, Virginia, Georgia, Iowa, Missouri, Minnesota, Wisconsin, Oklahoma, Texas, Kansas, and Nebraska. The scientific and engineering effort in this area totals 34.4 professional man-years per year with 6.7 devoted to basic principles and mechanics of water and wind erosion; 18.9 to interrelations of climate, soil, topography, cover, and management to wind and water erosion; 1.5 to equations for predicting soil and water losses; and 7.3 to practices, structures, and systems for modification of wind, water, and soil movement.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Principles and Mechanics of Water and Wind Erosion.

1. Mechanics of water erosion. Raindrop splash patterns and how they are affected by drop size and velocity, depth of surface water film, and angle of drop impact were investigated at Morris, Minnesota, to obtain a better understanding of the mechanics of soil erosion. High-speed movie photographs enabled methodical comparisons of splash configurations with respect to 4 descriptive parameters. For a constant drop size of 4.3 mm. diameter, the greatest average distance of splash occurred with a film of water 0.1 mm. deep over the target surface. The greatest quantity of splash occurred with a film depth of 0.5 mm. On a dry surface, splash did not occur unless the drop impact angle was greater than 40 degrees. With surface-film depth held constant at 0.5 mm., both quantity and distance of splash increased with increase in drop size and the resulting increase in terminal velocity. Also, with an increase in drop size, height and width of the splash cylinder increased, and the angle formed between the side of the splash cylinder and the horizontal target became smaller. Drops as large as 2.9 mm. remained nearly spherical in shape at their terminal velocity. Drops exceeding 4 mm. in diameter assumed a flattened "hamburger bun" shape. (SWC 8-c1)

Studies in New Hampshire using strain gages to measure raindrop impact forces revealed that, as a water film approached a critical depth, the impact force of raindrops increased, but as the depth increased beyond this point, impact forces decreased. The critical depth was a function of the waterdrop diameter. This study was extended to determine the effect on soil loss and it was found that this concept of a critical depth of water layer was reflected in the amount of soil loss from small cans. The actual amount of soil loss was also influenced by the angle of impact and number of drops impacting on a given point. (SWC 8-a1)

The influence of slope steepness, slope length, and particle size on soil movement under thin films of water were investigated in a laboratory study at Lafayette, Indiana, using noncohesive material (spherical glass beads) in lieu of soil. The exponents of both the slope-length and the slope-steepness factor increased substantially as particle size decreased

to the fine sand size. The length exponent ranged from 0.6 to 1.6 and the steepness exponent from 3.0 to 5.0 for these noncohesive particles. The interaction effect of particle size with length and steepness of slope was highly significant. Splash erosion rates were relatively insignificant compared to the erosion from runoff. When rill erosion was minor, bead movement by splash decreased with decreasing slope steepness and with increasing slope length due to increasing depth of flow, but after significant rilling it increased with increased slope length because of the increased surfaces exposed to drop impact between the rills. These results are from the initial phase of a larger study of the relation of erosion to slope and rainstorm characteristics as influenced by particle shape, cohesiveness, structure, and size. (SWC 8-c1)

2. Soil erodibility. Studies at Orono, Maine, using a laboratory rainfall simulator compared the effects of percent of rock cover and size of rocks on soil and water losses. A coverage of 5 and 20 percent of the area with rocks had little effect on soil loss, but there was a significant reduction at 35 percent coverage. Rocks 0.5 to 1.0 inch in diameter tended to decrease soil loss to a greater degree than did larger ones. The effect of rock coverage on water losses was not clearly defined. (SWC 8-a1)

In an in situ soil erodibility study under simulated rainfall in Indiana, those soils high in silt content were generally more erodible than the soils high in sand or clay content. Laboratory determinations of soil physical properties indicated that, of the properties tested, the three best indicators of soil erodibility were soil aggregation, suspension percentage, and soil texture. Particle size distribution of the sediment in the runoff indicated that the silt and clay fractions were removed in slightly greater proportions than the sand fraction in early stages of runoff. As runoff Continued for longer time periods, the percent sand usually increased. (SWC 8-c1)

In a study of 5 Iowa soils, the relation between soil loss and EI (the rainfall erosion index) was linear and the rate of increase in soil loss per additional unit of EI was nearly identical for all the soils except Ida. On the Ida, a silt loam high in coarse silt and relatively low in organic matter, the soil-loss rate increased more rapidly with the higher EI values. Of the other soils, the Marshall, Grundy, and Shelby were silty clay loams and the Kenyon a loam. Infiltration into the Ida dropped sharply for EI values above 110, resulting in increased runoff and erosion. This suggests that the soil-erodibility factor value for a given soil should be measured under the storm-size range responsible for the greatest portion of long-time total soil loss in that soils region. (SWC 8-c1)

At Lincoln, Nebraska, nearly one-half of the eroded material, carried in runoff from Keith very fine sandy loam and Sharpsburg silty clay loam on slopes ranging from 2.3 to 6 percent, was in the form of aggregates with diameters ranging from 100 to 250 microns. Detactment and transport

occurred throughout the plot length under simulated rainfall conditions. The rate of erosion in pounds per acre per hour was an exponential function of the discharge. (SWC 8-d1)

B. Interrelations of Climate, Soil, Topography, Cover, and Management to Wind and Water Erosion.

1. Water runoff and erosion. At Presque Isle, Maine, as in the past years, rock removal tended to increase both soil and water losses whereas crushing and returning rocks to the soil reduced these losses. Twice as much soil and 1.5 times as much water were lost from continuous potatoes as where potatoes were grown as part of a 3-year rotation with small grain and sod, but yields were not appreciably affected.

A study in New York to determine the rate at which eroded soils can recover their productivity under good management practices was started in 1942 using severely eroded land (ex-fallow) and noneroded land (ex-meadow). Yields of corn from the eroded area were 47 percent of those from the noneroded at the start, but after 1952 the differences in yield were about 10 percent and in 1962, 6 percent. Soil losses, however, were greater from the ex-meadow area indicating some degree of stabilization on the eroded area resulting from the exposure of stones. (SWC 8-a1)

The erosion-control effectiveness of sod preceding corn has not been masked by the present high-level forage and grain production. On the Marshall silty clay loam plots in Iowa, continuous corn receiving 160 pounds of nitrogen and yielding 119 bushels per acre lost 18.6 tons of soil in 1962, while rotation corn receiving 60 pounds of nitrogen and yielding 115 bushels per acre lost 8.2 tons of soil. In 1961, soil losses from the 2 treatments were 7.1 tons and 3.3 tons, respectively. On Ida silt loam in western Iowa, corn following oats with sweet clover catch lost 50 percent more soil than corn following a meadow sod. On the Barnes soil in Minnesota, second-year corn lost 36 tons of soil, whereas first-year corn after meadow lost 20 tons. Both yielded about 90 bushels of corn per acre.

In an Indiana-Illinois study in which 4 sod-based rotations were studied under simulated rainfall of high intensity, first-year row crops after meadow averaged 60 percent less soil loss than second-year row crops. Infiltration was 17 percent greater and sediment content of the runoff was 44 percent less with the first-year row crops. Differences in soil loss from corn following 2 or more years of meadow as compared with 1-year meadow were not statistically significant. (SWC 8-c2)

Similarly, in the South, the soil loss from row crops following sods was less than one-half that from row crops grown continuously on Tifton loamy sand, Cecil sandy loam, and Providence silt loam soils at Tifton, Georgia, Watkinsville, Georgia, and Holly Springs, Mississippi, respectively. (SWC 8-b1)

In Wisconsin, wheel-track planting of corn reduced erosion only 14 percent when residues of three previous crops had been removed. Another Wisconsin study indicated that the erosion-reducing effectiveness of heavy corn residues turned under with a moldboard plow becomes greater with successive years of the practice. In the second year of the practice, incorporating the corn stover with a moldboard plow was nearly as effective as leaving the stover at the surface by using a field cultivator to prepare the seedbed. About one-third of the stover turned under in 1961 had not decomposed and when the area was turnplowed again in 1962 it was mixed with the surface soil, where it was highly effective in reducing erosion. During the 1961 season the stover turned under had been less effective than that left at the surface by use of a field cultivator. (SWC 8-c2)

In Nebraska, studies indicate till-plant tillage systems for continuous corn production offer effective control of water erosion on Bridgeport very fine sandy loam with slopes of 3.4 percent. Till-plant systems with simulated rainfall applied at rates of 2.5 and 4.0 inches per hour reduced soil losses from 10.7 to 3.4 tons per acre or 64 percent when compared to a conventional moldboard plow treatment. Differences in infiltration were comparatively small. The till-plant system offers the advantage of maximum erosion protection by corn residue prior to planting and reduced soil disturbance from tillage (16 inches wide) plus savings in machine operation and labor during period of peak demand.

Stabilization of man-made slopes similar to those found in highway cuts and fills, ammunition bunkers, etc., requires water erosion control during the period when vegetative cover is established. At Lincoln, Nebraska, studies on Sharpsburg silty clay loam with 5 to 6 percent slope have shown that prairie hay mulches applied at rates of 2,000 and 4,000 pounds per acre and anchored with a rolling disc packer were equally effective in controlling soil erosion. Soil loss from mulched plots was nil compared to 7 tons per acre removed from bare plots when subjected to simulated storms of 1.4 hours duration and intensities of 2.5 inches per hour. (SWC 8-d1)

Studies in Wisconsin show that breaking soil crusts by cultivation is important when herbicides are used for weed control on corn with conventional seedbed preparation. Runoff was 1.2 inches and soil loss was 6.3 tons per acre when the corn was not cultivated, but only 0.3 inch of water and 1.2 tons of soil were lost when the corn was cultivated as needed to break the crusts formed by previous intense rains. The rough surface of the wheel-track-planted plots did not seal and did not require cultivation. (SWC 8-c2)

At Watkinsville, Georgia, 10 percent of an application of 5 pounds per acre of Atrazine was measured by chemical tests in the washoff from a simulated 1.25-inch rainstorm that followed by one hour the application of the chemical on the Cecil sandy loam soil. In studies with 2, 4-D during the summer of 1961, nearly 70 percent of the 2.2-pound application

of the chemical was recovered in the runoff and erosion resulting from a simulated storm of 3.75 inches in 1.5 hours. This 1961 washoff was five times that recovered in a December 1960 study. A bioassay method was used to measure the 2, 4-D washoff. (SWC 8-b1)

Certain soils in wheat-growing areas of eastern Washington which have highly developed profiles have been improved by mixing with a backhoe or deep plowing. At Rockford, Washington, mixing the A and B horizons of Freeman silt loam soil to a depth of 4 feet increased the growth and yield of alfalfa from 1 to 2 tons per acre. There was less heaving of alfalfa and greater water absorption and greater water use on the deep-treated plots. Deep plowing destroyed restrictive horizons and created a greater moisture-holding reserve as a result of a reduction in density of the B horizon. Measurable regrowth after the first cutting occurred only where the profile was mixed 48 inches deep, indicating more available moisture. (SWC 8-f1)

2. Wind erosion. At Manhattan, Kansas, an analysis of records on wind velocity and direction indicated that a definite prevailing wind erosion direction exists for most locations in the Great Plains. A map was prepared showing the prevailing wind erosion direction and relative degree of certainty of the analysis. This map will be of value in determining the best direction to orient field strips, shelterbelts, and emergency tillage so that they will be as nearly as possible at right angles to the prevailing wind erosion direction.

At Manhattan, Kansas, interpretative analysis of data from a study designed to obtain better information on the influence of different kinds, amounts, heights, and placements of crop residue on erosion of soil by wind indicated that a complex exponential equation combined with a power function is needed to fully express the relation between dependent and independent variables. Information of particular importance insofar as future development of the general wind erosion equation is concerned is that the rate of wind erosion varies exponentially with the amount of crop residue.

Stubble mulch tillage studies under semiarid climatic conditions at Alliance, Nebraska, and Colby and Garden City, Kansas, indicated: (1) During initial tillage of standing wheat stubble, the amount of crop residue conserved by a given tillage machine is related to height of stubble and amount of pretillage residue. During subsequent tillage, amount of pretillage residue has some effect, height or length of residue has very little effect, but previous positioning of residue has a strong influence on amount conserved. (2) Tillage sequences using subsurface tillage machines (sweeps) left more residue on the land surface at winter wheat seeding than combinations using one-way disks and sweeps. (3) Poor control of weeds, such as cheatgrass, was obtained with tillage sequences using any type of subsurface sweeps. (4) Sequences using one-ways produced significantly higher wheat yield than sequences using subsurface sweeps during 2 out of 3 years of this study.

At Big Spring, Texas, in the Southern Plains semiarid region, field experiments have shown that sweep tillage of sorghum stubble is an effective method to control wind erosion from the time sorghum is harvested until a stand of cotton is established. However, cultivation required for weed control in the cotton depletes sorghum residue so that the amount of residue remaining at cotton harvest is not adequate for wind erosion control. The only feasible method to control erosion then is to list the land deeply. (SWC 8-e1)

Studies at St. Anthony, Idaho, show that fallowing longer than one year increased the susceptibility of the surface to wing erosion. After one year of fallow, 91 percent of the surface soil clods were large enough to be considered resistant to wind erosion, but fields fallowed continually for 3 years had only 64 percent of clods of this size. When surface residue, surface roughness, and clod size are considered together, the 3-year fallow was about three times as susceptible to erosion as was the 1-year fallow. Fallowing longer than one year is sometimes practiced where acreage restrictions are involved. (SWC 8-f1)

C. Equations for Predicting Soil and Water Losses.

1. Water runoff and erosion. Soil erodibility factor values derived from the assembled data at Lafayette, Indiana, for 22 of the major soils represented on erosion research stations showed that values for silt loams ranged from 0.28 to 0.69; for clay loams, 0.26 to 0.32; for sandy loams, 0.22 to 0.28; for loamy sands, 0.08 to 0.10; and for flaggy or gravelly loam, 0.03 to 0.05. These values represent the average soil loss from fallow per unit of rainfall-erosion index, on 9 percent slopes 72.3 feet long.

Preliminary studies for development of an empirical equation expressing surface runoff as a function of rainfall, soil, topography, cropping, management, and their interrelations showed runoff amount per unit of rainfall energy held fairly constant for corn through the 3 cropstage periods from spring plowing to tasselling and increased in the 2 periods from tasselling to spring plowing, but for small grain declined significantly through each successive cropstage period. Crop residues incorporated into the plow layer were especially effective in reducing runoff. Across-slope tillage was much more effective in reducing surface runoff when crop residues were plowed down than when they were removed before plowing. (SWC 8-c3)

2. Wind erosion. At Manhattan, Kansas, significant advances have been made towards the completion of the universal wind erosion equation, as follows: (1) A map indicating the wind erosion climatic factor by increments of 10 percent was prepared, from existing weater records, for each state in the Great Plains; (2) twenty-seven charts for quick determination of conditions needed to reduce wind erosion to a tolerable

amount were developed; and (3) current and past research data on the influence of rough and smooth terrains on wind erosion were analyzed and a method of estimating the conditions required to control wind erosion for any degree of slope was developed and incorporated into the procedure of the wind erosion equation.

Also, at Manhattan, Kansas, a method of predicting the severity of wind erosion in susceptible regions at least 7 months in advance of its occurrence has been developed. The method employs a computation of a climatic index. The index is based on average temperature, precipitation, and wind velocity for a 3-year period ending May 31, to serve as an index of the potential severity of wind erosion during the forthcoming calendar year, January 1 to December 31. The index is a simple number expressed as percent of an average for a given location. If the index is greater than 125 percent, the danger of wind erosion is considered serious. When this happens, it is recommended that farmers take special precautions to control wind erosion. On the basis of analyzed data, a prediction of whether the severity of wind erosion would be above or below the critical 125-percent value will be accurate about 85 percent of the time. Much damage to crops and soils in the past occurred when farmers were unaware of impending dust storms. The predictions should have considerable value when combined with knowledge that farmers now have on how to control wind erosion. (SWC 8-e1)

3. Soil loss tolerance. At Manhattan, Kansas, a mathematical equation was developed which expressed definitions and concepts involved in such terms as "soil erosion tolerance" and "soil removal." Solution of the equation at any point of time and place involves: (1) Measure of present soil properties; (2) measure of soil property requirements for the future; (3) erosion (wearing away) of soil properties with time; and (4) renewal of (addition to) soil properties with time. Choice of solutions depends upon economic influences and preference or policy. (SWC 8-e2)

D. Practices, Structures, and Systems for Modification of Wind, Water, and Soil Movement.

1. Water runoff and erosion. Modern methods of farming require the elimination of short-point rows created by contour farming on rough sloping topography. A land forming study was initiated in 1961 in Virginia to eliminate this problem and provide a basis for an improved cultural system for tobacco. Three methods of land forming included: (1) Stockpiled topsoil, formed subsoil, and respread topsoil; (2) topsoil hauled in and uniformly spread on formed land; and (3) land formed without consideration for thickness or position of topsoil. Tobacco yields in 1962 were 1,876, 2,132, and 2,288 pounds per acre for (1), (2), and (3), respectively. There was no significant difference in tobacco quality. Fill areas yielded significantly better than cut or transition areas.

The cost was less than $100 per acre. Preliminary studies on the use of exposed subsoils for tobacco indicate that a straw mulch with adequate fertilization improves growth, probably by eliminating surface sealing and increasing the amount of water available for the crop. (SWC 8-a1)

Steps required in the construction of parallel terrace systems on farms in Georgia and South Carolina were: (1) Smoothing down old terraces; (2) smoothing the area between old terraces and filling gullies; (3) construction of waterways; (4) construction of new terraces; and (5) final grading between the terraces. Equipment used included large wheel-type tractors pulling bottomless scrapers, motor graders, and track-type tractors pulling earth movers. Records on 5 farms showed a wide variation in the cubic yards of earth moved from the waterway, between the terraces, and filling gullies. Terrace lengths varied from 318 to 481 feet per acre. Total construction costs varied from $8.26 to $21.04 per acre reterraced, and were affected by the type of equipment used, the amount of earth moved in smoothing the field and constructing the waterways, and the length of terraces per acre. (SWC 8-b2)

In a series of simulated rainfall tests in Minnesota on 13' X 75' plots on 4-, 7-, and 10-percent slopes, the erosion-control effectiveness of across-slope farming for corn was greatest on the 7-percent slope, and for oats, on the 4-percent slope. Overall, soil loss from the contoured corn plots averaged about 30 percent and from the contoured oats plots about 50 percent of that from the respective up- and down-slope plots. Surface runoff was reduced about 15 percent by contouring on the 4-percent and 7-percent slopes but was not reduced on the 10-percent slope plots. (SWC 8-c2)

2. Runoff water management for moisture conservation. A trend showing the success of Zingg conservation bench terraces on certain soils is being established at Bushland, Texas, Big Spring, Texas, and Hays, Kansas. On the fine-textured soils at Bushland, Texas, and at Hays, Kansas, the Zingg terrace system usually makes more efficient use of precipitation and runoff water caught in the system than conventional terraces or nonterraced land. But on a coarse-textured soil at Big Spring, Texas, the Zingg terrace system has not produced better conservation or utilization of precipitation and runoff than conventional farming systems without terraces. Yield increases due to runoff water caught in the benches at Big Spring have been small. It appears that the Zingg terrace system works best on soils with high waterholding capacity.

A study of land leveling and runoff water concentration for soil salinity control on drylands is continuing in the Rio Grande Valley of Texas at Weslaco. It was found that where runoff water was concentrated on saline soil, salt concentration was reduced. It was also found that where all rainfall was retained on the land, but no outside runoff water was added, soil salinity was not reduced. (SWC 8-e3)

3. Wind erosion. Field experiments at Manhattan, Kansas, (wet subhumid region) and Akron, Colorado, (semiarid region) showed that annual crop barriers, if properly oriented and spaced, can protect the soil surface from wind erosion. Barriers of sudangrass and grain sorghum were effective in providing protection for distances up to 14 times their height under a 30-mile-per-hour wind velocity measured at 50-foot height.

At Big Spring, Texas, studies of the effect of native perennial grasses between cotton rows on erodibility by wind indicated that grass-cotton systems were more effective in controlling erosion than were all-cotton systems. Wind tunnel tests run at right angles to row direction showed that on the poorest grass-cotton system, loss was only 35 percent of all-cotton, and losses from the best grass-cotton system were only about 2 percent of all-cotton losses. These grass-cotton row systems also appear to have good possibilities of reducing erosion without reducing income from the primary cash crop. (SWC 8-e1)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Basic Principles and Mechanics of Water and Wind Erosion

Palmer, R. S. 1962. An apparatus for forming waterdrops. U.S. Department of Agriculture Prod. Res. Rpt. No. 63: 28 pp.
Palmer, R. S. 1962. Water jet breakup from stainless steel tubes. Agr. Eng. 43 (8): 456-457.

Interrelations of Climate, Soil, Topography, Cover, and Management to Wind and Water Erosion.

Bertrand, A. R., and Mannering, J. V. 1963. Cut that crust! Crops and Soils 15 (6): 13-14.
Bertrand, A. R., and Sor, Kamil. 1962. The effect of rainfall intensity on soil structure and migration of colloidal materials in soils. Soil Sci. Soc. Amer. Proc. 26: 297-300.
Hauser, V. L., Van Doren, C. E., and Robins, J. S. 1962. A comparison of level and graded terraces in the Southern High Plains. Trans. Amer. Soc. Agr. Eng. 5 (1): 75-77.
Hermsmeier, L. F., Meyer, L. D., Barnett, A. P., and Young, R. A. 1963. Construction and operation of a 16-unit rainulator. U.S. Department of Agriculture, ARS 41-62: 136 pp.
Hermsmeier, L. F., and Young, R. A. 1962. Antisedimentation device for measuring flumes. Agr. Eng. 43: 648-649.
Horning, T. R. 1962. Cloddy seedbed saves both money and soil. Crops and Soils 14 (9): 25.
Horning, T. R., and Oveson, M. M. 1962. Cloddy and conventional seedbeds for wheat production in the Northwest. Agron. Jour. 54 (3): 229-232.
Mannering, J. V., and Meyer, L. D. 1963. The effects of various rates of surface mulch on infiltration and erosion. Soil Sci. Soc. Amer. Proc. 27 (1): 84-86.
Siddoway, F. H., and McKay, H. C. 1962. Tillage of sweetclover under dryland conditions. Idaho Agr. Ext. Serv. Bul. No. 388, 12 pp.
Weakly, H. E. 1962. Aggregation of soil carried in runoff from simulated rainfall. Soil Sci. Soc. Amer. Proc. 26 (5): 511-512.
White, A. W., Jr., Sparrow, G. N., and Carter, R. L. 1962. Peanuts and corn in sod-based rotations. Georgia Agr. Res. 4 (2): 5-6.

Equations for Predicting Soil and Water Losses

Chepil, W. S., Siddoway, F. H., and Armbrust, D. V. 1962. Climatic factor for estimating wind erodibility of farm fields. Jour. Soil and Water Conserv. 17 (4): 162-165.
Smith, D. D. and Wischmeier, W. H. 1962. Rainfall erosion. Advances in Agronomy, Vol. 14, pp. 109-148, Academic Press, Inc., New York, New York.
Wischmeier, W. H. 1962. Rainfall erosion potential, geographic and location differences of distribution. Agr. Eng. 43(4): 212-215, 225.

Wischmeier, W. H., and Smith, D. D. 1962. Soil-loss estimation as a tool in soil and water management planning. Internatl. Assoc. Scientific Hydrology, Publ. No. 59: pp 148-159.

Practices, Structures, and Systems for Modification of Wind, Water, and Soil Movement.

Chepil, W. S., Moldenhauer, W. C., Hobbs, J. A., Nossaman, N. L., and Taylor, H. M. 1962. Deep plowing sandy soil. U. S. Department of Agriculture Prod. Res. Rpt. No. 64: 14 pp.

Chepil, W. S., Woodruff, N. P., Siddoway, F. H., Fryrear, D. W., and Armbrust, D. V. 1963. Vegetative and nonvegetative materials to control wind and water erosion. Soil Sci. Soc. Amer. Proc. 27: 86-89.

Hauser, V. L., and Cox, M. B. 1962. Evaluation of the Zingg conservation bench terrace. Agr. Eng. 43 (8): 453-454, 457.

Hauser, V. L., and Taylor, H. M. 1963. Deep tillage of High Plains hardland soils. Texas Agr. Prog. 9 (2): 7-8.

AREA 9: MOISTURE CONSERVATION FOR THE EFFICIENT AND EFFECTIVE USE OF PRECIPITATION ON CROPS AND RANGELANDS

Problem. Inadequate moisture is the main factor limiting growth in the 200,000 acres of cultivated and 300,000 acres of rangeland that make up the Great Plains. In this area, the frequency and amount of precipitation have significant social and economic consequences. In most cases, the precipitation received is more than adequate to support good plant metabolism and to provide water for other uses if some means of reducing the large loss of water by evaporation and transpiration were available. The amount of moisture needed for actual plant metabolism is only a small fraction of the moisture actually transpired by the plant. The amount of water used for transpiration is, in turn, usually less than the amount lost directly from the soil by evaporation.

The intense nature of much of the rainfall together with fast melting of snow overlying frozen soils causes runoff and sometimes floods. In many instances, this runoff occurs over a profile that is only partially filled with water. Because crop yields are directly related to stored soil moisture at planting time, research is seeking ways to increase this storage in the soil profile. Methods of controlling infiltration on a wide variety of soil conditions are being developed. Research in this area is also directed toward finding methods for decreasing evaporation and controlling transpiration by physical or chemical means.

USDA PROGRAM

The Division conducts both basic and applied research and development in the area of moisture conservation, utilizing soil physicists, soil chemists, soil microbiologists, and agricultural engineers. Research evaluating the physical factors associated with increasing the infiltration of water are being studied at Bushland, Big Spring, Temple, and Weslaco, Texas; Pendleton, Oregon; St. Anthony, Idaho; Riverside, California; Mandan, North Dakota; and Akron, Colorado. Studies to determine the basic relationships between climatic factors and the loss of water by evaporation are being done at Fort Collins, Colorado; Mandan, North Dakota; Riverside, California; Big Spring and Weslaco, Texas; and Akron, Colorado. Methods of reducing evapotranspiration are being studied at Mandan, North Dakota; Fort Collins and Akron, Colorado; Pendleton, Oregon; Riverside, California; Big Spring, Weslaco, and Temple, Texas; and Manhattan, Kansas. At all locations, the work is done cooperatively with the respective state experiment stations.

The Federal scientific effort devoted to research in these areas totals 15.6 man-years. Of this total, 6.1 are devoted to factors affecting infiltration; 6.0 to basic relationships between climatic factors and the loss of water by evaporation; and 3.5 to methods of reducing evapotranspiration.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Factors Influencing Moisture Storage

1. Tillage. A three-year study at Morris, Minnesota, has shown that plowing alfalfa land late in the summer or in the early fall can be an effective means of conserving moisture for the following year. The additional water stored following plowing has increased corn yields the succeeding year by as much as 14 bushels per acre. (SWC 9-c1)

At St. Anthony, Idaho, experiments with wheat have demonstrated that late plowing (late June) to prepare a summerfallow and early seeding (mid-August) reduces the amount of available moisture remaining in a 6-foot profile in late October. The combination of early plowing (early May) and early seeding (mid-August) resulted in grain yields of 42 bushels per acre as compared to 33 bushels per acre on the late-plowed plots. (SWC 9-f1)

Post-harvest chiseling of coarse-textured silt loam soil at St. Anthony did not increase the amount of moisture stored in the soil the following spring. On the finer-textured silt loam soils in this area, chiseling after harvest has consistently increased the amount of stored moisture. (SWC 9-f1)

2. Landforming. In the Plains' States, landforming appears to be the most practical means of increasing water storage in the soil. At Akron, Colorado, during the winter of 1961-1962, 1.3 inches of available moisture was stored on the benches and 2.3 additional inches of water was stored during the growing season. Forage sorghum yields on the benches were 13 tons per acre as compared to 5 tons on the adjacent check strips. The crop production on the bench per inch of water used was twice that attained on the adjacent check strips. (SWC 9-d1)

During a 3-year period, 1959-1962, at Mandan, North Dakota, wheat yields on the conservation benches have averaged 8 bushels more per acre per year than on the contributing slopes. During 1962, an extremely wet year at Newell, South Dakota, water was impounded on the benches for several days after very large storms. This flooded condition decreased the yields of grass seed on the benches as compared with those of the contributing slopes. This experiment demonstrates the need for surface drainage on conservation benches during wet seasons. (SWC 9-d1)

At Fort Collins, Colorado, conservation benches with an impervious contributing area gave barley yields twice as high as those obtained on a crop-fallow system. Conservation benches without contributing areas did not increase soil moisture storage or crop yields under dryland conditions at Weslaco, Texas. At Big Spring, Texas, sorghum yields on conservation benches were the same as those on the contributing area. (SWC 9-d1 and SWC 9-e1)

3. Chemical fallow. Chemical summerfallow has continued to show promise in comparison with mechanical and mechanical plus chemical summerfallow at Pendleton and Moro, Oregon. Atrazine or simazine (1.6 lbs/A) and amitrole (1 lb./A) applied in January and 2, 4-D (1.5 lbs/A) in the summer gave complete control of weeds. In a 4-foot profile, chemical fallowing resulted in production of 23 pounds per acre more nitrate-nitrogen at Pendleton and 10 pounds per acre more at Moro than was produced by mechanical fallowing. The major differences in nitrate-nitrogen content occurred in the 0- to 3-inch soil layer. At Sidney, Montana, moisture storage with chemical fallow was less than for conventional mulch fallow. The complete chemical fallow system resulted in less erodible surface soil than the soil under the stubble mulch system. (SWC 9-f1 and SWC 9-d1)

4. Snow management. At Akron, Colorado, studies show that at least 15 to 17 inches of snow are required before snow conservation is practical. The density of snowdrifts has been found to be three times that of adjacent level snow. Snow fences with a wood density of about 21 to 31 percent were found to deposit the greatest volume of snow. Snowdrifts formed by standard snow fences at Sidney, Montana, increased the soil moisture from 1.8 inches to 4.8 inches of water over a 30-foot width near the fence. Snow management can conserve considerable water in the Great Plains during most seasons. (SWC 9-d1)

5. Freezing and thawing. Soil moisture movement studies at Mandan, North Dakota, have shown that most movement occurs during periods of rapid temperature change during the freezing process. At Bozeman, Montana, the moisture content of the deepest frozen depth in a field soil increased from 23 to 32 percent. The moisture was apparently drawn from the unfrozen subsoil. This information if of great value in properly interpreting drops in the water tables during the winter months. (SWC 9-d1)

6. Cropping. At Newell, South Dakota, the infiltration rate of an old grass legume stand on Pierre clay was three times that of a cultivated soil. The infiltration rates for western wheatgrass plots at Archer, Wyoming, were four times greater than where the vegetation was shortgrass. When the wheatgrass areas were clipped, the infiltration rates decreased. The data from these experiments show that moisture conservation can be increased by good range management practices. (SWC 9-d1)

7. Soil texture. Analysis of available moisture storage capacity and mechanical composition of some Missouri soils shows that the available moisture storage capacity is directly related to the silt content and inversely related to the clay content of the soil. (SWC 9-c1)

B. Factors Affecting the Loss of Water by Evaporation

1. Percentage of precipitation lost as evaporation. During the last year, estimates were made of the water balance at Mandan, North Dakota. Of the 15.7-inch annual average precipitation, 79 percent is used as evapotranspiration during the growing season; about 3 percent evaporates directly from the soil between harvest and fall freezing; about 9 percent is lost by runoff from snowmelt; and about 7 percent evaporates from the soil between the spring thaw and planting time. (SWC 9-d1)

2. Adsorbed ions. The mobility of soil water has been found to be influenced by adsorbed ions, according to the results of a laboratory test at Fort Collins, Colorado. For sodium-saturated mineral surfaces, the mobility of the first layer of water molecules was one-third that of water in bulk as compared to a mobility of one-twentieth that of bulk water for calcium-saturated systems. (SWC 9-d1)

3. Soil texture. In a field study at Riverside, California, the moisture loss over a 12-week summer period was 2.8, 3.6, 3.2, and 1.4 inches for a loamy sand, sandy loam, very fine sandy loam, and a clay soil, respectively. Nearly all of the moisture loss was attributed to evaporation. The depth of moisture loss ranged from 18 inches in the clay to 60 inches in the loamy sand. Efficiency for retaining available moisture over the summer period ranged from 33 percent for loamy sand to 73 percent for clay. The knowledge gained from these experiments will be of value to technicians in making recommendations to farmers. (SWC 9-g1)

4. Surface drying. Under laboratory-controlled conditions at Weslaco, Texas, soil columns dried under different ambient temperature and humidity conditions indicated that the rate of drying drops off rapidly as soon as the soil surface becomes visibly dry. Results showed that moisture could be conserved by inducing rapid initial drying of the soil surface. (SWC 9-e1)

5. Vapor movement. Observations of soil moisture storage and depletion on Pullman silty clay loam at Bushland, Texas, points up the importance of moisture movement in the vapor phase and the transmission of free water through shrinkage cracks. In these studies on which small grains and sorghums were grown, moisture gains occurred in the 2- to 6-foot soil depth in amounts that could not be explained by the amount of precipitation that occurred. Also, during two dry springs, significant losses of stored

moisture have occurred throughout the 6-foot depth of soil. It is generally assumed that soil moisture below 2 feet is not subject to loss by evaporation. In several instances, unmistakable gains of moisture have occurred in the third and fourth foot of soil over a three-week period even though no rain fell. (SWC 9-e1)

C. Factors Influencing the Use of Moisture by Crops

1. Stored soil moisture. In field studies conducted in western Minnesota and eastern South Dakota, it was found that few soil profiles are fully charged with moisture at planting time. The available water storage at 28 of 75 locations ranged between 6 to 8 inches in a 5-foot profile that was capable of holding 12 inches. In two of the three years the study was underway, the stored soil moisture at planting time was related to corn yield. When rainfall during the critical growth period (July 1 to August 15) was above normal, the importance of stored available moisture at planting was minimized. A multiple regression equation relating stored soil moisture at planting time and rainfall during successive 2-week intervals throughout the season accounted for 70 percent of the variation in corn yields during a 2-year period. (SWC 9-c1)

2. Calcium carbonate zone. At Bushland, Texas, there was a sharp discontinuity in water use by warm-season grasses where a zone of calcium carbonate began. The water above the lime layer was exhausted rapidly, but a considerable length of time was required to extract that below the lime layer. (SWC 9-e1)

A study at Fort Collins, Colorado, using data from the long-term studies at Akron to relate soil characteristics and climate to crop response, showed the depth to the accumulation zone of calcium carbonate to be highly correlated with crop yields. A single, easily measured soil property such as depth of the calcium carbonate zone may offer some possibility as a method for quickly assessing relative productivity of soils that develop from similar parent material and are under the same general influence of climate and vegetation. (SWC 9-d1)

3. Leaf area. Water use by two types of cotton with varying leaf areas was studied at Big Spring, Texas. Although the results were not conclusive, water use efficiency was greater with cotton plants of standard leaf type as compared to cotton plants with small (okra-type) leaves. (SWC 9-e1)

4. Row direction. Observation of plant growth at Big Spring, Texas, in a system of two rows of cotton alternating with one skip row revealed that when the rows were oriented north-south, the cotton row with the vacant row to the west outyielded by 19.5 percent the cotton row with the vacant row to the east. This yield difference appears to be associated with the small microclimatology differences in the diverse row direction. (SWC 9-e1)

5. Water table. At Weslaco, Texas, soil moisture measurements at various growth stages of dryland grain sorghum growing in an area with a seasonal water table indicate that a substantial portion of the moisture used by the crop came from the water table. During the growing season, the water table declined from 60 inches at seeding to 72 inches at maturity. (SWC 9-e1)

6. Crop varieties. The water use efficiency of several sudangrass varieties and related forage sorghum varieties at Akron, Colorado, indicates about a two-fold difference due to varieties. This is mostly due to differences in yield as water use was about equal for all varieties. Sudangrass showed much faster recovery from clipping than forage sorghum. Nitrogen application had no influence on yields or water use efficiency. (SWC 9-d1)

7. Phenological stage. Using Akron, Colorado, data, a series of studies directed toward associating climate with response to treatments and practices for the purpose of developing prediction criteria have shown that the period of heading to maturity of winter wheat appears to be the most critical of the phenological periods. For wheat growing on fallow, temperature and evaporation for this period are the most important factors followed by wind velocity. For continuous wheat, the most significant factor was evaporation, followed by temperature, precipitation, and wind velocity. Farmers in this area produced winter wheat with 50 to 60 percent less water per bushel during the past 20 years than was required for the production of wheat in the 20-year period 1909 to 1928. (SWC 10-d6)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Factors Influencing Moisture Storage

Bowers, S. A., Hanks, R. J., and Stickler, F. C. 1963. Distribution of net radiation within sorghum plots. Agron. Jour.-Notes 55: 204-205.

Burnett, E., Godfrey, C., and Oakes, H. March 1962. Soils of the Big Spring Field Station. Texas Agr. Expt. Sta. MP-559, 12 pp.

Haas, H. J., and Willis, W. O. 1962. Moisture storage and use by dryland spring wheat cropping systems. Soil Sci. Soc. Amer. Proc. 26(5): 506-509.

Hanks, R. J., and Bowers, S. A. 1962. Numerical solution of the moisture flow equation for infiltration into layered soils. Soil Sci. Soc. Amer. Proc. 26: 530-534.

Hauser, V. L., Van Doren, C. E., and Robins, J. S. 1962. A comparison of level and graded terraces in the Southern High Plains. Amer. Soc. Agr. Engin. Trans. 5(1): 75-77.

Willis, W. O., and Carlson, C. W. 1962. Conservation of winter Precipitation in the Northern Great Plains. J. Soil & Water Conserv. 17(3): 122-123, 128.

Factors Affecting the Loss of Water by Evaporation

Bowers, S. A., and Hanks, R. J. 1962. Specific heat capacity of soils and minerals as determined with a radiation calorimeter. Soil Sci. 94: 392-396.

Qayyum, M. A., and Kemper, W. D. 1962. Salt concentration gradients in soils and their effects on moisture movement and evaporation. Soil Sci. 93: 333-342.

Wiegand, C. L. 1962. Drying patterns of a sandy clay loam in relation to optimal depths of seeding. Agron. Jour. 54: 473-476.

Willis, W. O. 1962. Effect of partial surface covers on evaporation from soil. Soil Sci. Soc. Amer. Proc. 26(6): 598-601.

Willis, W. O. and Haas, H. J. 1963. Stretching dryland moisture. North Dakota Farm Res. Bimonthly Bul. 22(9): 4-6.

Factors Influencing the Utilization of Moisture by the Crop

Horning, T. R., and Oveson, M. M. 1962. Stubble-mulching in the Northwest. USDA Agr. Inform. Bul. 253, 28 pp.

Olsen, S. R., Watanabe, F. S., Kemper, W. D., and Clark, F. E. 1962. Effect of hexadecanol and octadecanol on efficiency of water use and growth of corn. Agron. Jour. 54: 544-545.

Ramig, R. E., and Rhoades, H. F. 1962. Nitrogen needs also depend on soil moisture. Crops and Soils 14(6): 24.

Ramig, Robert E., and Rhoades, H. F. 1963. Interrelationships of soil moisture level at planting time and nitrogen fertilization on winter wheat production. Agron. Jour. 55: 123-127.

AREA 10: SOIL PROPERTIES, PROCESSES, AND MANAGEMENT IN RELATION TO THE CONSERVATION AND EFFICIENT USE OF LAND AND WATER RESOURCES

Problem. Soil structure and tilth are manifested in all subject matter areas of soil and water conservation. Most of the conservation practices are in one way or another affected by the structural attributes of the soil. Although the importance of structure and tilth in soil and water conservation is very evident, these attributes are difficult to evaluate on a quantitative basis. The fundamental mechanisms of soil structure formation must be understood before residue management systems, tillage methods, and cropping systems can be developed that will improve and preserve soil tilth.

Most of the pesticides and growth regulators used in agriculture are applied to the soil or ultimately reach the soil. The fate of these compounds in the soil must be known in order that predictions of residual amounts in soil and water resources with continued use may be made. The amount of money spent by the American farmer for commercial fertilizer now exceeds 1.25 billion. In spite of all the research effort that has gone into plant nutrition research, we are not yet able to predict with confidence what will happen in any given case. Studies are continuing on the interactions of various environmental factors upon the primary fertility factors, including factors relating microbiology to fertility problems.

A decline in organic matter and plant nutrients is usually observed with cropping in all parts of this country. Water moves into and through the soil more slowly as the organic matter declines and plants use water less efficiently as the plant nutrient level decreases. Minor element deficiencies are being observed in most states. Knowledge is lacking as to how to supply the nutrients at optimum levels for plant growth and also the most economical way and form to apply them.

USDA PROGRAM

The Division program involves microbiologists, chemists, physicists, and plant phsiologists working on basic and applied problems associated with developing principles for soil and water conservation. Nutrient requirements and balance research is being conducted at New Brunswick, New Jersey; Ithaca, New York; Beltsville, Maryland; Thorsby, Alabama; Watkinsville, Georgia; Rio Piedras, Puerto Rico; Florence, South Carolina; State College, Mississippi; Morris, Minnesota; Ames, Iowa; Fort Collins and Grand Junction, Colorado; Huntley, Bozeman, and Sidney, Montana; Newell, South Dakota; Bushland, Weslaco, and Big Spring, Texas; University Park, New Mexico; Tucson, Arizona; Brawley, California; Prosser, Washington; and Pendleton, Oregon. Research concerned with soil chemical properties is being conducted

at Beltsville, Maryland; State College, Mississippi; Auburn, Alabama; Rio Piedras, Puerto Rico; Watkinsville, Georgia; Morris, Minnesota; Fort Collins, Colorado; Mandan, North Dakota; Weslaco, Texas; Prosser, Washington; Corvallis, Oregon; Brawley and Riverside, California; and Logan, Utah.

Tillage, residue management, and cropping systems research is being conducted at Orono, Maine; Ithaca, New York; State College, Pennsylvania; Blacksburg, Virginia; Florence, South Carolina; Watkinsville, Georgia; Morris and Minneapolis, Minnesota; Ames, Iowa; Akron, Colorado; Bozeman, Montana; Newell, South Dakota; Sidney, Montana; North Platte, Mitchell, and Lincoln, Nebraska; Bushland, Big Spring, and Temple, Texas; Woodward, Oklahoma; Pendleton, Oregon; and St. Anthony, Idaho.

Soil microbiology research is being conducted at Beltsville, Maryland; Minneapolis, Minnesota; Fort Collins, Colorado; Lincoln, Nebraska; and Prosser, Washington.

The Federal scientific effort devoted to research in these areas totals 97.2 professional man-years. Of this number, 29.6 are devoted to nutrient requirements-uptake and balance; 19.2 to soil chemical properties; 39.6 to tillage, residue management and cropping systems; and 8.8 to soil microbiology. At all locations, the work is done in cooperation with the experiment stations in the respective states.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Nutrient Requirements--Uptake and Balance

1. Recovery of applied nitrogen. Losses of fertilizer N under modified field conditions, using N^{15} fertilizers, were studied at Thorsby, Alabama. Over a 2-month period, presumed gaseous losses from various treatments ranged between 10 and 20 percent. Generally, greater loss occurred from nitrate fertilizer than from ammonium fertilizer; fallow soil lost more fertilizer N than soil cropped with sudangrass; and pH effects within the range of 4.5 to 7.0 were minor. In a preliminary test covering a longer time, a 30-percent loss was indicated after 10 months and a 60-percent loss after 14 months. This high percentage loss needs to be verified before its significance can be assessed. (SWC 10-aB2)

The recovery of N^{15}-labelled ammonium sulphate fertilizer in successive crops was studed in the greenhouse at Beltsville. Approximately 62 percent was utilized by the first crop (oats), 7 percent by the second (sudangrass), 3 percent by the third (also sudangrass), and 10 percent was unaccounted for. About 18 percent remained in the soil. A higher percentage of fertilizer was taken up by the first crop at the 400-pound rate of fertilization than at the 200- or 100-pound N rates. (SWC 10-aB2)

The recovery of urea nitrogen fertilizer was evaluated in a 3-year lysimeter study at Gunnison, Colorado, using timothy as an indicator crop. The total nitrogen recovered in the grass tops was 53, 53, and 42 percent for the 200-, 400-, and 800-pound annual rates, respectively. In this study, no nitrogen was lost by leaching. (SWC 10-d2)

At Bushland, Texas, about 30 percent of the applied nitrogen was recovered in the plant tops of irrigated blue grama (Bouteloua gracilis) grass. In this study, nitrogen gave substantial yield increases. The recovery was about 62 percent in an adjacent sudangrass study. (SWC 10-e2)

In a crested wheatgrass-nitrogen fertilization study at Newell, South Dakota, about 70 percent of the nitrogen applied in NH_4NO_3 (up to 640 pounds of N per acre) cannot be accounted for as inorganic nitrogen in the soil or as nitrogen removed in the hay. On nearby nonirrigated plots, removal in the hay has been lower than on the irrigated plots. The difference in removal is offset by the presence of more nitrate N in the 18- to 48-inch depth in the soil of the dryland plots. No statistically significant differences in various organic nitrogen fractions in the soil due to nitrogen fertilization have been detected. High variation in sampling of field soils may mask differences in organic nitrogen fractions that laboratory studies predict should have existed. (SWC 10-d2)

Sugar beets appear to recover a higher percentage of fertilizer nitrogen than grass. At Huntley, Montana, sugar beets absorbed 71, 79, and 55 percent, respectively, of 100, 200, and 400 pounds of nitrogen applied as ammonium nitrate. (SWC 10-d2)

Delayed reaction or slowly available fertilizers show potential for increasing use and recovery of applied plant nutrients. In greenhouse studies at Weslaco, Texas, nitrogen uptake by blue panic grass from resin-coated ammonium nitrate was 24 percent greater than that from uncoated ammonium nitrate. In earlier studies, sweet bell pepper yields were increased with coated urea. (SWC 10-e2)

At Riverside, California, the use of resin-coated urea overcame the problem of reduced grain emergence from placing readily soluble nitrogen fertilizer with seed under low moisture conditions. Noncoated urea applied at 30 and 60 pounds of nitrogen per acre reduced seedling emergence 19 and 41 percent, respectively, whereas coated urea had no deleterious effect. (SWC 10-g2)

A nitrification inhibitor, 2-chloro-6-(trichloremethyl) pyridine, was tested at Brawley, California, (at 0, 1, 2, and 5 percent levels) with ammonium nitrate, ammonium sulfate, urea, and calcium nitrate applied to nitrogen-deficient cotton at the rate of 100 pounds of nitrogen per acre.

Petiole nitrate-nitrogen analyses showed that the inhibitor effectively reduced nitrate concentrations when used with ammonium sulfate and urea, but this did not increase cotton yields. The use of the inhibitor with ammonium nitrate or calcium nitrate had little effect on either cotton yield or petiole nitrate concentration. (SWC 10-g1)

The movement of fertilizer constituents in soils dictates their availability and efficiency of use in crop production. Studies have been conducted on the ion and water movement that takes place around a band of sodium nitrate introduced into moist sandy soils. The model which has been developed to account for the observed nitrate movement is as follows: Water from the surrounding soil moves to the band as a result of osmotic forces and a concentrated solution of sodium nitrate accumulates. When a sufficient amount of this solution accumulates, a rapid downward flow in the soil occurs. This mass flow accounts for the rapid downward movement of nitrate away from a fertilizer band. Subsequent experiments have shown that much of the downward movement of nitrate from a band can be eliminated by placing a simple impermeable shield under the band. Field studies are being planned for the 1963 growing season in an attempt to find a practical method of shielding fertilizer bands. (SWC 10-aB7)

2. Mineralization of nitrogen. Evaluation of a commercial micro-Dumas (Coleman Nitrogen Analyzer) in relation to the standard Kjeldahl procedure for total nitrogen at Fort Collins, Colorado, has shown that it gives comparable results for soils with less than 3000 ppm total nitrogen, but that it gives high values for plant materials and soils with more than 3000 ppm nitrogen. Use of gas chromatography on the combustion gases showed that the high values were due to evolution of methane along with nitrogen gas. The micro-Dumas apparatus gives values comparable to the Kjeldahl if the N_2 of the combustion gases is resolved on a gas chromatograph or if a platinum catalyst is put in the postheater tube. The micro-Dumas apparatus has the advantages that it does not take a special room, is rapid, and includes nitrate nitrogen; but like the Kjeldahl procedure, it does not include indigenous fixed ammonia. The apparatus can be easily adapted for determination of total carbon. (SWC 10-d2)

At Fort Collins, Colorado, studies have continued on the chemical and microbial transformations of nitrogen in relation to the organic matter and mineral characteristics of Northern Plains' soils. Some soils, particularly subsoils, contain considerable nonexchangeable or fixed ammonia. Studies show that only a portion of this indigenous fixed ammonia is measured in the conventional Kjeldahl procedure for total soil nitrogen and that the fixed ammonia can be included only if the soil is pretreated with hydrofluoric acid to disrupt the clay mineral lattices in which the fixed ammonia is bound. Various hypothesis have been advanced for the lower fixed ammonia content and fixation capacity of surface soils as compared to subsoils. Research has shown that the fixation capacity can be reduced by

treating the soil with simple organic compounds and then drying the soil before fixation capacity is measured. This finding supports the hypothesis that organic matter reduces the ammonia-fixing capacity of the soil. (SWC 10-d2)

In ammonium fixation studies at Beltsville, N^{15} was used to permit a sensitive measurement of the release of fixed ammonium over a long period of time in the presence of other cations, including nonlabelled ammonium. The free and exchangeable ammonium was removed by washing with KCl, $CaCl_2$ or $N^{14}H_4Cl$ and the effect of the leaching cation on the uptake of the fixed ammonium by plants was measured. At the end of the first crop of sudangrass, only the calcium chloride-leached soil had released a significant amount. Possibly, the calcium ion aided the release of fixed ammonium by expanding the interlayer spacing of the clay minerals. (SWC 10-aB1)

Previous work at Beltsville has shown that nitrite N may accumulate to toxic levels in some light-textured Coastal Plains soils that have been heavily fertilized and treated with green manures. This is correlated with ammonia concentrations that appeared to be high enough to exhibit the Nitrobacter organisms that oxidize nitrite to nitrate. Further studies showed that when the cation exchange capacity of such soil was varied by mixing with sand or bentonite, the nitrite accumulation was inversely related to the cation exchange capacity. It was further found that nitrification was directly proportional to the distance between particles of the organic N source. These results are interpreted to mean that adsorbed ammonia is not toxic to Nitrobacter and that if the ammonia concentration can be kept low by increased cation exchange capacity or by gradients between particles, nitrification can proceed and nitrite will not accumulate. (SWC 10-aB2)

Studies of soil organic matter at Corvallis, Oregon, necessitated developing a rapid, accurate method for determining carbon in soils and soil extracts. A commercial carbon analyzer was adapted for making these determinations by adding an auxiliary furnace in the gasline to ensure complete combustion of carbonaceous material. This modification resulted in recovery of approximately 100 percent of the total carbon present; the more commonly used procedure permitted recovery of only about 90 percent of the total carbon. (SWC 10-f3)

Laboratory studies at Corvallis, Oregon, showed that ammoniation of air-dry layer silicates resulted in collapse of mineral lattices to 10 A for vermiculite and 12.6 to 15.2 A for variously treated montmorillonites. Some of the minerals expanded when water was added to the ammoniated minerals, whereas others did not. This difference in behavior is indicative of the different energies with which the ammonia is held by the minerals. The ammoniated minerals retained more ammonia when subjected to vacuum degassing than when allowed to degas in the open atmosphere. This phenomenon is explained on the basis of competition for adsorption between water vapor and ammonia gas when open to the atmosphere, but not in the closed system

used for vacuum degassing. Thus, when the ammoniated minerals were allowed to degas in the open air, water vapor replaced part of the adsorbed NH_3 which was lost from the mineral. Ammoniated soils, when left open to the atmosphere, continually lost adsorbed NH_3 over a period of several months, but when allowed to equilibrate for 24 hours, retained approximately 0.7 me. of NH_3 for each millequivalent of cation exchange capacity. These studies are timely in view of the widespread use of anhydrous NH_3 as fertilizer. (SWC 10-f2)

3. Nutrient requirements of various crops. A reexamination of the significance of nutrient balance in relation to fertilizer usage has continued at Beltsville. The effects have been studied of various combinations of fertilizer salts on ionic content and growth of several crop species, (including oats, barley, millet, and buckwheat.) Substantial evidence has been accumulated to support the contention that in the production of high yields one of the functions of the cations Ca, Mg, Na, or K is to supply positive charges. Further, the relative uptake rates of ions differ between plant species and, consequently, the various combination of fertilizer salts do not produce the same stress on the ionic balance for each plant species. (SWC 10-aB8)

At Bozeman, Montana, in a study to determine the importance of nitrogen at early stages of wheat development, the results showed that the nitrogen level may be low during the first weeks and yields would not be reduced. When nitrogen was completely withheld from Thatcher spring wheat plants for one or more weeks initially, with adequate N supplied thereafter, there were fewer tillers, fewer secondary roots, and a decreased dry matter production of the tops and roots at harvest. Results were the same when low rates of N (less than 9 ppm) were supplied for the first two or more weeks. The data indicated that inadequate rates of N enhanced early root development at the expense of top production. After 4 weeks of plant growth, the low rate resulted in a 40-percent increase in root production but a 73-percent decrease in top production when compared to the adequate N treatment (224 ppm N). (SWC 10-5)

In Alabama, the production of 10 tons of oven-dry Coastal Bermudagrass forage required 600 pounds of nitrogen per acre. Clipping the grass at 21-day intervals instead of 32-day intervals reduced total yields 2 tons per acre. (SWC 10-b3)

In Puerto Rico, Napier grass pasture on steep slopes in the mountain region fertilized with 392 pounds of N, 49 pounds of P, and 232 pounds of K produced 1400 pounds of beef gain per acre annually for the past 4 years. Potassium applications of 166 and 664 pounds of K per acre produced 8.5 and 15 tons per acre of Napier grass containing 1.0 and 1.6 percent of K, respectively. (SWC 10-b3)

Studies on fertilization of rangeland in southern California indicated a significant residual effect of nitrogen and phosphate on annual range production when the season of application was dry. Increases in dry matter yield from the residual effect of fertilizer applied on annual range the previous year varied from 500 pounds per acre for 30 pounds of nitrogen to 3,289 pounds for 120 pounds of nitrogen and 26 pounds of phosphorus. A more rapid early growth of annual range vegetation resulting in earlier range readiness for grazing was obtained by nitrogen and phosphate fertilization. (SWC 10-g2)

Nitrogen and phosphorus fertilizer markedly changed the relative contribution of the various annual range species to total forage yield. In general, nitrogen increased grasses and decreased legumes. The application of 26 pounds of phosphorus per acre doubled the contribution of Bicolor lupine to range forage production. Nitrogen, at 120 pounds per acre with the same amount of phosphorus, increased wild oat production nearly sixfold, and reduced lupine production 75 percent. Phosphorus applications reduced the nitrogen content of the range forage in proportion to the amount of phosphate added. (SWC 10-g2)

At Newell, South Dakota, moisture added to a representative soil of the Pierre-Promise soil association as a result of water spreading in 1962 produced approximately one-third more western wheatgrass, one-third more short grass, and more than five times less nongrass species on a native range site than where water was not spread. The use of nitrogen fertilizer in conjunction with water spreading altered the botanical composition the first year by increasing the amount of western wheatgrass, decreasing the short grass species, and increasing slightly the nongrass species. The application of 120 pounds of nitrogen per acre where water was spread produced an additional ton of native hay in 1962, while the same fertilizer treatment applied on the dry range produced three-quarters of a ton of additional forage. (SWC 10-d3)

At Woodward, Oklahoma, nitrogen fertilizer increased wheat yields in four out of the five years it was used. Similar wheat yield increases from N were obtained at Cherokee on both a stubble mulch and clean tillage system. (SWC 10-e2)

Sweet sorghum grown on nitrogen-deficient Holtville silty clay near Brawley, California, responded to nitrogen applications of up to 300 pounds, with maximum yields of 43 tons green weight per acre. (SWC 10-g1)

Prediction of plant nutrient needs from soil tests, plant tissue tests, and from field studies continues to receive considerable attention. At Weslaco, Texas, it was determined that the critical leaf N level of sweet bell peppers during the first 100 days of plant growth was approximately 4 percent. In other studies at Weslaco, rate of production of available nitrogen in the soil was found to be more effective than total soil nitrogen in predicting dry matter and N yield levels. At Bushland, Texas, evaluation of the practice of fertilizing to predetermined levels in lieu of using

arbitrarily chosen factorial fertilizer rates in fertility studies is being continued. Results obtained in 1962 substantiate those obtained in 1960 and 1961, and indicate that fertilization to predetermined levels yields more usable information for the amount of work performed than the older method does. This approach utilizes the productivity status of the soil being examined and places fertility experimentation on a more sound basis than conventional arbitrary selection of rates. (SWC 10-e2)

4. Influence of soil texture and moisture on phosphorus diffusion. At Mandan, North Dakota, several laboratory methods were correlated with values of phosphorus availability obtained in the growth chamber. Several surface (0-7-inch depth) and subsoils (7-21-inch depth) from sites in 13 western states were used in this study. The sodium bicarbonate soluble phosphorus "A" values as determined by the Fried and Dean method and the total phosphorus in plants all proved to be good predictors of soils that would respond to phosphorus fertilizer. The sodium bicarbonate soluble phosphorus also proved to be a good predictor of phosphorus responses in the field. (SWC 10-d1)

At Fort Collins, Colorado, measurement of the bulk diffusion coefficient of phosphorus (D_p) in soils showed that the few values reported in the literature appear to be too small by factors of 100 to 1000. Failure to consider the capacity factor in the soil-P system probably accounts for these low values. The values obtained at Fort Collins include the capacity factor, and their agreement with D_p values calculated from chloride diffusion constitute evidence, but not final proof, that this approach is a valid and accurate way to measure D_p for soil P. Diffusion coefficients may be applied in several ways to obtain a more complete and accurate definition of the soil solution-plant root system. Diffusion coefficients were measured on three soils at two moisture tension levels. The method developed appear to be applicable to other soils and to porous systems in general in which a definable relationship exists between the concentration of the ion in solution and the amount and nature of the same ion in the solid phase. Differences in the diffusion coefficients of phosphorus between sandy and clay soils were applied to explain variations in rates of P uptake by corn seedlings at equal initial concentrations of P in the soil solution. The relation between labile P of the solid phase and P concentration in solution also varies with the clay content. An equation relating uptake of P by plant roots to these two factors showed that the rate of uptake was approximately proportional to the square root of D_p X b where D_p is the diffusion coefficient and b is the slope of the line relating labile P to concentration of P in solution, when other factors are constant. The equation predicts that the rate of uptake of P will be one-third as much from the sandy soil as from the clay soil at equal concentrations of P in the soil solution. Actual measurement of the rate of P uptake by corn roots agreed closely with the predicted values from the equation for P concentrations less than 0.2 ppm.

As the clay content of three soils increased from 17 to 51 percent, the diffusion coefficient for P increased from 1.1×10^{-7} to 6.7×10^{-7} cm^2/sec. and the b value increased from 110 to 178. These findings provide a much sounder basis for making phosphorus recommendations for various soil types. (SWC 10-d1)

5. Influence of soil moisture and temperature on phosphorus nutrition. At Bozeman, Montana, studies of uptake of radioactive phosphorus by wheat in relation to soil moisture showed that no phosphorus was taken up from dry soils and that shower or weather conditions that keep the soil wet for only a day or two do not permit uptake of fertilizer phosphorus from surface soils. The time required to detect significant phosphorus uptake after P and water application in the surface soil is proportional to the age of the plant. Adequate phosphorus in solutions for the first five weeks for spring wheat growth and none thereafter provided sufficient phosphorus for maximum growth. Withholding phosphorus for the first two or three weeks of growth severely reduced yield even if ample phosphorus was supplied thereafter. Similar relations were found for nitrogen. (SWC 10-d3)

In controlled soil temperature studies at Mandan, North Dakota, optimum soil temperatures for spring barley growth were near 59° F. Increasing the available P supply, through either increased available soil P or by P fertilization, greatly increased the soil temperature range over which nearly maximum growth occurred. Growth responses to P fertilization were relatively uniform at most soil temperatures on a soil medium in P availability, but much greater at soil temperatures near 59° F. than at other temperatures on a low P soil. Low soil temperatures were more adverse to top growth than to root growth, but high soil temperatures had the opposite effect. At 45° F., dry matter production increased very little with increased percent P in the plant material, suggesting that cool temperatures interfered with physiological mechanisms other than those concerned with P uptake and metabolism. At 80° F., percent P in the plant material was high, but dry weights continued to increase as percent P increased. (SWC 10-d3)

The temperature at which soils were incubated for 50 days at Mandan, North Dakota, had little influence on water or $NaHCO_3$-soluble P at low and intermediate levels of available P. However, at high P levels, incubation temperatures above 59° F. resulted in reduced P solubility in water and $NaHCO_3$. Soluble P concentrations after incubation were closely related to growth and total P uptake of barley grown under similar conditions. Changes in $NaHCO_3$-soluble P due to cropping were related to total P uptake. The uptake of fertilizer P by barley was much more sensitive to soil temperature than soil P uptake. (SWC 10-d1)

A study of the effect of soil temperature on the mineralization of organic P at Fort Collins, Colorado, indicated that this source of supply

contributed a small but significant part of the total supply to the plant, particularly on unfertilized soils. Efforts to measure by chemical means the amount of organic P that mineralized during incubation were only partially successful. (SWC 10-d1)

Crested wheatgrass plots fertilized with P in the spring at Mandan, North Dakota, had higher $NaHCO_3$-soluble P concentrations in the fall than those not fertilized. Plots receiving calcium nitrate or urea had lower $NaHCO_3$-P contents than those receiving no N, ammonium nitrate, or ammonium sulfate. This occurred both with and without added fertilizer P. (SWC 10-d1)

Greenhouse studies at State College, Pennsylvania, showed that on soils low in available phosphorus, growth of both grass and legume seedlings was greatly increased by phosphate fertilization. Studies in nutrient solution cultures showed that growth of young seedlings was severely retarded by complete withdrawal of phosphorus from the root zone for periods of several days, such as may occur when the surface layer of soil becomes too dry for uptake of phosphorus applied as a topdressing. These findings add a great deal to our knowledge of how phosphorus fertilizer response is influenced by soil temperature and moisture conditions. (SWC 10-a2)

6. Micronutrients. Frequent chlorosis in crops of western Minnesota has created many questions by farmers and farm advisors as to possible micro-element deficiencies and corrective treatments. On areas thought to be zinc deficient, applications of as little as five pounds of zinc as zinc sulfate per acre either broadcast and plowed down or banded with nitrogen resulted in economically beneficial yield increases of corn. A good relationship was found between visual zinc deficiency symptoms and the concentration of zinc in the plant. On selected sites of anticipated zinc deficiency, early growth of corn was retarded when amounts of zinc applied as zinc sulfate greater than 10 pounds per acre was banded or 20 pounds broadcast. (SWC 10-c1)

Soybeans (PI and Chippewa), kidney beans, corn, and dill were used as indicator plants in the field for zinc and iron deficiencies in the soil. Of four locations studied, one site showed a positive response to both iron and zinc additions, one a positive iron response, one a limited zinc response and one no response to either iron or zinc. PI soybeans, kidney beans, and dill were the best indicators of zinc deficiencies, and PI soybeans and kidney beans were sensitive to iron deficiencies. The indicator crop technique has merit in assessing the cause of chlorosis in the western Minnesota area. (SWC 10-c1)

Field studies with the Russet Burbank potato conducted at Prosser, Washington, showed that increasing rates of phosphorus fertilizer applied without zinc increased the incidence of zinc deficiency symptoms on the plants. It was also shown that under many circumstances, the zinc concentration was the same in deficient and normal plants. There appears to be a mutual antagonism between zinc and phosphorus in the nutrition of

this variety of potato. For example, where 16 pounds of zinc per acre were applied, the zinc concentrations in potato stems were 71 and 14 ppm. at the 0 and 320 pounds of P per acre level, respectively. Similarly, where 320 pounds of P per acre were applied, the phosphorus content of the stems was decreased from 1.310 percent where no zinc was applied to 0.300 percent at the 16-pound-per-acre zinc level. Because of this interaction between phosphorus and zinc, the zinc content of the plants does not appear to be a reliable indicator for diagnosing zinc deficiency for this crop. (SWC 10-f1)

Laboratory studies at Prosser, Washington, have shown that the solubility of Si is markedly decreased by the presence of Al as the pH is increased from 5.5 to 9.0. Similar effects of pH on the solubility of Si in soils have been noted, and thus, the presence of Al may prove to be the causative factor. (SWC 10-f2)

Soils with various lime contents were collected in Israel and used in a micronutrient greenhouse experiment. Clover (Trifolium alexandrinum L.) showed symptoms of chlorosis in the highly calcareous soils, but the element involved was not determined. Some progress was made on extractants for the various elements under study. (A10-SWC-12)

In Poland, studies to determine the distribution of micronutrients in soil minerals have shown that all of the trace elements are concentrated in the clay fractions. This is especially true of those soils developed from granite. The availability of these micronutrients to plants will have to be evaluated in order to determine how important these findings might be. (E21-SWC-7)

7. Nutrient requirements of subsoils. Soil fertility studies in the greenhouse, on both surface soil and subsoil from two locations in Maine, indicate that soil fertility should not be a major problem in growing potatoes on subsoils exposed during land forming. Soil tests showed a higher level of available nutrients in the topsoil than in the subsoil. At each of several levels of fertilizer application, the yields of tubers grown on subsoil compared favorably with yields on topsoil. For one location, the average yields for all fertilizer treatments were higher on subsoil than on topsoil. (SWC 10-a1)

Soil management studies on problems associated with land forming were initiated on Piedmont soil in Virginia following removal of the surface soil. The subsoils proved to be very deficient in available nitrogen and required liberal fertilization. A heavy straw mulch (3 tons per acre) greatly improved soil moisture relations on these plots. The straw prevented soil crusting and undoubtedly increased infiltration in addition to decreasing evaporation. Straw incorporated in the soil in addition to the mulch appeared to give little if any benefit over the mulch alone. (SWC 10-a1)

Greenhouse, laboratory, and field studies conducted at Bushland, Texas, indicate that loss of topsoil from Great Plains soils of aeolian or alluvial origin may be compensated by application of fertilizers. Studies on genetic horizons of Amarillo, Dalhart, Miles, Reinach, Grant, Pullman, Abilene, and Spearville soils have shown that the subsurface horizons of these soils can be made equally or more productive than their topsoils through application of fertilizers. In a field study, Pullman silty clay loam soil from which 12 inches of topsoil had been removed produced yields equivalent to uncut soil. A 16-inch cut area yielded only 10 percent less than uncut soil. These yield relationships were obtained in the two seasons following that in which the cuts were made. Since loss of topsoil can be compensated by application of fertilizers, topsoils can be sacrificed for benefits obtained from moisture conservation practices such as bench leveling, land leveling, or similar land forming operations. On soils that have heavy clay subsoils or where rocks are found near the surface, the loss of surface soil can seriously reduce yields. (SWC 10-e2)

B. Soil Chemical Properties

1. Soil-pesticide complexes. A simple and rapid spectrophotometric method useful in studies of adsorption and desorption of 4, 6-bis(alkylamino)-s-triazines by and from clay minerals and soil was developed. The ultraviolet adsorption maxima of more than 40 of these compounds were determined, and it was found that there was a close relationship between max. and phototoxicity to oats as reported in the literature. It seems possible that the relative toxicities of untested triazines could be predicted from their respective wavelength maxima. (SWC 10-aB4)

Additional studies have been conducted on the behavior of simazine in soils. The distribution of simazine added to soils in solution is influenced by the soil moisture conditions. If the upper soil horizons are moist, more simazine infiltrates into the lower horizons. The adsorption of simazine tends to decrease with increasing soil pH. (SWC 10-aB4)

2. Influence of soil reaction on plant growth. Previous work at Beltsville has shown that certain acid soils contain toxic levels of Al. The degree of the toxicity of aluminum seems to vary among soils. Therefore, the effect of a chelating agent on the toxicity of aluminum to different plant species has been studied. The results suggest that an aluminum chelation mechanism may explain the differential aluminum tolerance of plant species and the differential aluminum toxicities of acid soils have the same pH and extractable aluminum levels but different organic matter contents. (SWC 10-aB8)

A further evaluation of the growth-limiting factors in acid Bladen soil has shown copper deficiency to be a serious yield-limiting factor for barley when this soil is limed and fertilized. A prominent characteristic of copper deficiency in this barley was a reduced translocation of calcium to the new leaves. (SWC 10-aB8)

Calcitic lime was more effective than dolomitic lime in raising soil pH in Fleming and Watkinsville, Georgia, and Oakley and Holly Springs, Mississippi. Lime applications on the surface and those mixed with the top 6 inches of soil were equally effective on yield of grasses in Georgia, Mississippi, and Puerto Rico. (SWC 10-b1)

Growth chamber experiments at Auburn, Alabama, have shown that when the surface soil is adequately fertilized, cotton roots develop normally in a substrate devoid of phosphorus, but die when calcium is lacking. Cotton roots were damaged directly by a level as low as 0.5 part per million of soluble aluminum but not by high levels of manganese. The development of cotton and sudangrass roots in subsoils was depressed markedly by pH levels within the range commonly found in Coastal Plains subsoils. In a field experiment at Headland, Alabama, seed cotton yield increased from 1,500 pounds per acre at subsoil pH levels less than 4.5 to 2,800 pounds at pH levels of above 5.5. These data suggest that in soils that have acid subsoils, the lime must be placed deep in the profile if cotton roots are expected to penetrate the subsoil. (SWC 10-b6)

C. Tillage, Residue Management, and Cropping Systems

1. Soil structure. Previous work at St. Paul, Minnesota, has shown that the compounds of significant interest in binding soil crumbs could be divided into at least three groups according to ease of removal from the system, i.e., NaCl extraction, pyrophosphate extraction, and others not removed by any extractant tried. During this year, sodium periodate has been used as a "chemical hammer" to remove some of the bonds not removed by NaCl and pyrophosphate. Using this technique, indications have been found that both polysaccharides and humic substances are important in stabilizing grassland and virgin soils of high organic matter content. Results of the studies so far indicate that other constituents are active in forest soils. (SWC 10-c3)

Studies at Ames on a number of Iowa soils indicate that aggregates exist in cultivated soils for long periods of time. On several loess-derived Brunizem soils, the exterior of aggregates was higher in organic matter than the interior. Root and residue decomposition on the surface of the aggregate and better water-air relationships at the surface probably account for the higher organic matter content of the surface. Likewise, the organic matter content of small aggregates was usually higher than that of large aggregates, perhaps because of a higher surface area-mass ratio. (SWC 10-c2)

Farmers spend considerable effort on tillage to create what is thought to be a desirable secondary soil aggregate size around planted seeds. However, little is known about the effects of secondary aggregate size on soil-water-air relationships. Studies at Ames, Iowa, on three soils have shown that as aggregate size increased, the volume of large pores within

the aggregate increased, resulting in a decreased bulk density and a decreased content of water held at suctions greater than 0.1 density and a decreased content of water held at suctions greater than 0.1 bar. At suctions equal to or greater than 0.1 bar, only negligible amounts of water were held in the voids among aggregates. Moisture-suction relationships were shown to be influenced by both size of the aggregates and packing arrangements, especially at suctions less that approximately 1 bar. (SWC 10-c2)

A study was made at Madison, Wisconsin, of the factors affecting infiltration in tilled soils. Infiltration differences among the four rotations and six soil cover and tillage treatments studied were attributed primarily to differences in the number, size, and vertical continuity of the large soil pores or voids. On the Miami soil, the amount of water infiltrated from simulated rainfall was about equal from continuous corn with a mulch cover and corn without mulch following four years of hay. On soils that had alfalfa in the rotation, the infiltration rates were higher than in nonlegume rotations. (SWC 10-c2)

Both winter cover crops and wood chips increased aggregate stability and yield of dry beans in a five-year vegetable rotation of sweet corn, beans, tomatores, cabbage, and peas at Marcellus, New York. Yields of dry beans in 1962 ranged from 2,426 pounds per acre on plots with winter cover crops and wood chips (7 tons per acre per year) to 1,813 pounds on plots without cover crops or wood chips. All plots were fertilized. (SWC 10-a1)

At Marlboro, New Jersey, sod crops and cover crops in a vegetable crop rotation improved soil tilth over a seven-year period as measured by aggregate stability, bulk density, and hydraulic conductivity. Crop yields were not affected by the improved soil tilth conditions. (SWC 10-a1)

2. Tillage. In Minnesota and South Dakota, corn yields were compared when the soil was tilled in the conventional manner and when untilled except for placement of the seed in the soil. On a Barnes soil in both 1961 and 1962, the untilled treatment yielded decidedly less than the conventionally tilled treatment. However, on a Nicollet-Webster and a Poinsett soil, yields from the untilled and tilled soils were not different. (SWC 10-c2)

In northwest Iowa on a Moody soil under moisture deficient conditions, corn yields from listing and cultivator-plant (plowing followed by a light cultivating and planting in one operation) were 88 bushels per acre, whereas yields from conventional and wheel-track planting were 56 and 52 bushels per acre, respectively. Moisture-conserving tillage treatments such as listing have repeatedly yielded more corn during dry years on the Moody soil. Under good moisture conditions on a Galva soil, corn yields averaged over 100 bushels per acre and were not greatly different from 5 methods of

tillage, although rotary tillage was decidedly inferior when compared at high plant populations (17,000 plants per acre). On a Grundy soil, corn yields over a 6-year period averaged 126 bushels per acre for conventional, and from 111 to 115 bushels for mulch, ridge, listing, and wheel-track tillage. (SWC 10-c2)

In Watkinsville, Georgia, no significant differences were found in corn yields due to different tillage and mulch treatments, but corn yields were significantly higher on land with a 2 percent slope than on a 7 percent slope. At Holly Springs, Mississippi, an evaluation of tillage practices for corn grown on loess soil showed that the highest corn yield of 88 bushels per acre was obtained using a lister-planting machine, compared to 76 bushels for the tractor-track planting. (SWC 10-b5)

In the mountain region of Puerto Rico, sweet potatoes, corn, taniers and yams were grown as successfully with no land preparation as with complete land preparation. However, tobacco produced 174 pounds more per acre with complete land preparation. (SWC 10-b5)

In the "alfalfa sickness" area of northeastern Washington and adjacent Idaho, alfalfa seeded on soil mixed as deep as 4 feet showed a marked response to depth of mixing. Without fertilizer of any kind, forage yields from second year growth were increased from 0.4 ton per acre (conventional plowing) to 1.6 tons per acre where the soil was mixed to a depth of 4 feet. Application of lime, sulfur, phosphorus, molybdenum, and boron further increased the yield to 1.3 tons per acre for conventional plowing and 3.3 tons per acre where the soil was mixed to 4 feet. The benefits derived from mixing the soil may result from (a) increasing the effective depth of soil (moisture storage), (b) supplying nutrients from the subsoil, (c) diluting toxic substances, and/or (d) preventing damage to plants from frost heaving. Frost heaving damaged first-year alfalfa more severely when seeded with a companion crop than when seeded alone, and deep mixing greatly reduced plant damage by this mechanism. (SWC 10-f1)

At Watkinsville, Georgia, planting corn directly in grass sods provided excellent runoff and erosion control, but yields were unsatisfactory in dry years. Fescue offered the corn less competition for moisture than did Coastal Bermudagrass. (SWC 10-b4)

A point quadrant instrument was developed at Morris, Minnesota, for measurement of microsoil surface elevations and total porosity of the tilled layer. Large apparent differences in capacity to detain water, as inferred from total porosity, were observed among preplant tillages and combinations of preplant and postplant tillage systems. The effects varied, however, with soil type and moisture content of the soil at the time of tillage. The total porosity of the tilled layer on Barnes and Nicollet-Webster soils did not decrease greatly during the growing season on treatments that did not receive mechanical cultivation. Mechanical cultivation materially decreased porosity, although the porosity at the

end of the growing season was materially greater than before tillage in the spring. The geometry of the soil surface changed during the season as a result of exposure and cultural operations. (SWC 10-c2)

Tillage practices for corn, ranging from minimum tillage to excessive tillage, were studied during 11 years of continuous corn at Marcellus, New York. Soil tests for bulk density, noncapillary porosity, and aggregate stability showed small differences in favor of minimum tillage. In most years, yields of corn were not significantly affected by tillage practices. However, in years when significant differences have occurred, the lowest yields were on the excessively tilled plots. (SWC 10-a1)

3. Tillage pans. An important advancement has been achieved in understanding the cause of root-restricting pans, which sometimes occur on large acreages of soils throughout the Southern Plains. A six-year study at Bushland, Texas, indicates that high strength soil layers cause the shallow root development. Many geographical areas contain soil layers that potentially will cause shallow rooting, but when root-restricting pans do occur, they are high strength soil layers activated by drought conditions early in the growing season. A full recognition of the changes that excessive soil strength can cause in root growth patterns will profoundly affect tillage practices throughout the nation. On many soils, the primary goal of tillage will be the reduction of excessive soil strength. Critical penetrometer limits are being developed at Bushland, Texas, to provide a practical means for evaluating the effects of tillage on high strength soil. (SWC 10-e1)

Results at Bushland, Texas, indicate that a close correlation exists between the percentage of cotton seedling taproots penetrating a soil layer and the strength of that layer. For several soils, the critical limit where no roots penetrated the layer was 400 psi as measured by a static penetrometer. When the high strength pans cause raidal restraints of cotton roots early in the growing season, cotton yields are drastically reduced. If the restraint occurs after midseason, cotton yields are only slightly affected. (SWC 10-e1)

The effects of particle size distribution within the sand fraction upon soil strength were investigated. When subjected to the same compactive effort, multicomponent sands gave greater soil strength and greater bulk density than single component sands. Both soil strength and bulk density decreased as the moisture content at the time of compaction decreased. (SWC 10-e1)

Four years after plowing a Pullman soil to a depth of 24 inches, the bulk density of the 9- to 21-inch zone was appreciably lower than the area not plowed. Even after decades, soils disturbed by installing tile drains at Weslaco, Texas, had lower bulk density in the 2- to 7-foot depth than adjacent undisturbed soil. These two observations indicate that drastic profile disturbance may be effective for substantial periods in the Southern Plains. (SWC 10-e1)

At Auburn, Alabama, a satisfactory technique was devised for measuring the separate effects of subsoil compaction and of oxygen level on cotton primary root penetration of test subsoil cores. As bulk density was decreased, oxygen became progressively more important, and at bulk densities of 1.5 and below oxygen was the controlling factor in rate of root penetration. The ability of the roots to penetrate the subsoil cores decreased rapidly below about 10 percent oxygen. (SWC 10-b6)

4. Stubble and plastic mulches. Studies at Akron, Colorado, on Rosebud silt loam soils indicated that the soil nitrate level at planting time was inversely correlated with increased amounts of stubble at the end of the fallow period. Straw and grain yields varied directly with the nitrate nitrogen supply at seeding time. In years of heavy straw production, tillage practices other than subsurface operations should be used in order that some of the residue may decompose before planting time. (SWC 10-d5)

A 20-year fallow-management experiment conducted at St. Anthony, Idaho, has shown that the organic matter content of the soil was maintained at about 3 percent where 2 tons per acre of straw was returned to the soil after each crop. Where all straw was burned, the organic matter content of the soil was decreased to about 0.9 of what it was at the beginning of the experiment. (SWC 10-f1)

In Thorsby, Alabama, the use of black plastic to cover the soil surface increased corn yields by reducing evaporation from the soil during the early stages of growth, thus making more moisture available for plant use later in the season when water requirements were higher. (SWC 10-b5)

At Marcellus, New York, light-colored plastic mulches markedly increased early growth and final yield of corn. The better growth early in the spring is attributed largely to increased soil temperature under the plastic. Differences in soil moisture, although small, probably contributed to the increased yields of grain from the mulch. On plots where the plastic was sealed to the corn stalks, yields of 100 bushels per acre were produced. The corn plants used only the moisture stored in the soil at planting time. In northern Maine, a clear plastic mulch greatly increased the early growth of potatoes. Potato yields were not influenced by the plastic treatment, but the specific gravity of the tubers was increased. At Blacksburg, Virginia, a black plastic mulch did not affect the yield or quality of flue-cured tobacco. The time of harvest was not influenced by this treatment. (SWC 10-a1)

5. Cropping systems. Significant residual effects of previous rotation crops and fertilization were measured on Billings silty clay loam in 1962 at Grand Junction, Colorado. Legume and nonlegume rotations and continuous cropping systems were uniformly cropped to corn in 1962. Corn following 1, 2, and 3 years of alfalfa produced good yields due to the residual effects of alfalfa from previous years. Corn following corn and corn following barley were low in yield on both rotations. Nitrogen deficiency as shown by low percent N in the corn leaf was attributed to the previous

crop. Yields were considerably greater where the previous crop was either three- or six-year rotation sugar beets or continuous beets. The effect of residual nitrogen in increasing corn yield on the three- and six-year rotations was apparent as contrasted to yields from unfertilized treatments. Yields from corn after corn on the three-year rotation had declined to the same level as continuous corn for nine years where both had received nitrogen fertilizer in the rotation period. (SWC 10-d3)

Studies at the U. S. Regional Pasture Research Laboratory at State College, Pennsylvania, on the difficult problem of reestablishing Ladino clover in grasslands show that competition for soil moisture is a critical factor. Fertilizer must also be applied, and clipping or grazing controlled to prevent excessive shading of the clover seedlings. (SWC 10-a2)

A comparison of various cropping practices in Imperial Valley, California, showed that Coastal Bermudagrass resulted in a higher rate of water infiltration, more root growth, and lower soil salinity levels than alfalfa, sesbania, or row crops. (SWC 10-g1)

In studies on Piedmont soil in Georgia, Coastal Bermudagrass was the only sod which reestablished itself following corn. A greenhouse study at Watkinsville, Georgia, showed that where fertilized rye or vetch was included in a continuous corn system, the soil nitrogen-supplying power was increased over that of continuous corn alone by the equivalent of 45 pounds per acre of nitrogen. (SWC 10-b4)

D. Soil Microbiology

1. Decomposition of crop residues. At Beltsville, studies were continued on the effect of fresh plant residue in soil on the rate of decomposition of native organic matter. Contrary to some reports in the literature, the freshly added residue labelled with C^{14} did not accelerate release of soil carbon. In fact, the decomposition of several plant materials, especially root tissue of wheat and corn, actually suppressed decomposition of the native organic matter. The plant materials tested provided a range of species, maturity stage, and C/N ratios. (SWC 10-aB3)

Prolonged drying of soil was previously shown to result in a more rapid evolution of CO_2 upon subsequent wetting, although neither the microbial count nor mineral N levels changed during that time. It has been found that both light and temperature are the important variables. Samples dried under continuous light showed a much higher rate of subsequent CO_2 evolution than did those incubated in darkness. Drying at 30° C. had a more pronounced effect than drying at 20° C. The indications are that the gradual increase in CO_2 evolution rate after drying may be due to chemical or physical changes that render the organic matter more available to microbial action. (SWC 10-aB3)

In stubble mulch studies at Lincoln, Nebraska, it was found that patulin is the phytotoxic substance produced by the fungus, Penicillium urticae Bainer. Patulin, which reduced germination and root and shoot growth in the laboratory, is produced by a number of fungi. Under field conditions the subsequent effect of this compound on field crops remains to be ascertained. Water extracts of wheat straw and sorghum stover were slightly toxic to seedlings of western wheatgrass, switchgrass, Holt Indian grass, sideoats grama, blue grama and bluestem. In addition, phytotoxic substances were isolated from a soil with residues left on the surface. The results of these studies give some explanation as to why reduced yields have occurred in some farmers' fields. (SWC 10-d5)

2. Antibiotics. A method, much more sensitive than previously available, has been developed whereby minute quantities of antibiotics added to soils can be recovered. The technique, using extraction with suitable buffers and vacuum concentration of the extract, detected 40 µg of terramycin or 10 µg aureomycin in 500 grams of soil (equivalent to about 18 and 4.5 grams per acre, respectively). The method will be of value in investigating the occurrence of naturally produced antibiotics in soil. (SWC 10-aB3)

3. Modifying bacterial strains. The transformation process in bacteria, whereby genetic characters can be transferred from one strain to another closely related strain, appears to have promise as a method of combining desirable N-fixing properties in improved strains of legume rhizobia. Initial attempts were made to transform antibiotic resistance factors among selected Rhizobium strains with negative results. Inconclusive evidence was obtained that the chlorosis-inducing factor in some soybean strains could be transferred to others. (SWC 10-aB6)

Rhizobial polysaccharides were investigated as possible genetic markers for transformation studies, but presently available diagnostic methods by means of infrared analysis were found to be unsuitable for this purpose. As a supplement to the polysaccharide study, the effects of these substances on gel formation in clay suspensions were tested by means of viscometry. Some correlation between gel stability and previously reported soil-aggregating ability was found. (SWC 10-aB6)

4. Influence of plant residue decomposition on root diseases. The survival of plant pathogenic micro-organisms in soil is influenced by the decomposition of plant residues. However, not enough is known about this effect to make use of it in management practices for root disease control. Streptomycin-resistant potato scab organisms were isolated at Prosser, Washington, by selecting mutant strains of otherwise sensitive organisms. The mutants retain their pathogenicity to White Rose potatoes, and are morphologically and physiologically indistinguishable from the streptomycin-sensitive parent cultures. These cultures can be used in direct assays of survival and population fluctuations of the organism by plating inoculated soil on streptomycin-containing media. (SWC 10-f4)

5. Rhizobia-induced chlorosis in soybeans. Certain strains of soybean rhizobia in association with specific varieties of soybeans will induce chlorosis in the host. The competitiveness of strains was tested at Beltsville and was found to be inversely related to the degree of chlorosis of the inoculated plant. (SWC 10-aB6)

It has been found that the chlorosis-inducing compound (apparently a new amino acid) occurs in response to an interaction between the genotypes of the bacteria and soybean. Extending these studies to the complement of free amino acids in the soybean nodule showed that most of the differences observed with various soybean-rhizobia combinations were controlled by rhizobia genotype. However, one unidentified amino acid appeared to be a product of host-rhizobia interaction. Arginine production was apparently host-controlled. (SWC 10-aB6)

In further chemical investigation of the chlorosis-inducing compound, which included elemental analysis, it appears that at least part of the molecule is a hydroxy-diamino monocarboxylic acid with the tentative formula $C_8H_{18}N_2O_3$. This amino acid does not induce chlorosis, but is believed to be either a precursor or otherwise closely related biosynthetically to the active compound. (SWC 10-aB6)

Some progress is being made in bacteriophage studies in Poland, and it is possible that some of their phages may be temperate. If this is true, it will be a big step forward in speeding up our research on genetic transformation. Some of the Polish serological work with rhizobia strains may also tie-in with our research on competition and identification of strains of legume bacteria in field soils. (E21-SWC-6)

6. Inoculation of legumes. Alfalfa grown in greenhouse pots at Prosser, Washington, on severely affected soil from the "legume sickness" area of northeastern Washington and northern Idaho showed marked response to inoculation with effective rhizobia. It appears that these affected soils are extremely low in effective nitrogen-fixing bacteria, despite the fact that alfalfa has been grown successfully in this area for many years prior to development of the "legume sickness" problem. Culture studies have indicated the presence of many native rhizobia capable of invading alfalfa roots and forming nodules, but apparently they are incapable of furnishing the nitrogen needs of the crop. On the other hand, isolates taken from occasional healthy plants growing in fields of sick plants were highly efficient nitrogen-fixing strains, but they were greatly outnumbered by inefficient strains. (SWC 10-f4)

Several soil samples have been collected from Indian rice paddies and a procedure is being worked out to make the samples bacteria free by the use of ultraviolet radiation. Indian scientists are concerned about the contribution algae might be making to the fertility of the soil. (A7-SWC-7)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Nutrient Requirements--Uptake and Balance

Abruna, F., and Vicente-Chandler, J. 1963. Effects of six sources of nitrogen on yields, soil acidity, and leaf composition of coffee. Jour. Agr., Univ. Puerto Rico. 47(1): 41-46.

Adams, W. E., and Jordan, H. V. 1962. Cotton response to sulfur on Cecil soil. Georgia Agr. Res. 3(3): 8-9.

Alban, L. A., Cushman, H. E., and Hunter, A. S. 1962. Fertilizer recommendations for wheat in the Columbia Basin of Oregon. Oregon (Corvallis) Agr. Ext. Bul. 806: 13 pp.

Barrows, H. L., and Simpson, E. C. 1962. A study of interferences in the EDTA titration of Ca and Mg in plant tissue analysis. Amer. Soc. for Hort. Sci. Proc. 80: 650-660.

Barrows, H. L., and Simpson, E. C. 1962. An EDTA method for the direct routine determination of calcium and magnesium in soils and plant tissue. Soil Sci. Soc. Amer. Proc. 26: 443-445.

Black, A. L., and Greb, B. W. 1962. Nitrate accumulation in soils covered with plastic mulch. Agron. Jour. 54: 366.

Boawn, L. C. 1962. Zinc fertilization of Russet Burbank Potatoes. 1st Annual Washington State Potato and Vegetable Conf. Proc., Wash. (Pullman) Agr. Ext. Serv., 39-40.

Boawn, L. C., and Leggett, G. E. 1963. Zinc deficiency of the Russet Burbank potato. Soil Sci. 95(2): 137-141.

Boawn, Louis C., Crawford, Carl L., and Nelson, J. L. 1963. Evaluation of the nitrogen status of corn by tissue tests. USDA ARS 41-76, 11 pp.

Clark, Francis E. 1962. Losses of nitrogen accompanying nitrification. Trans. Interntl. Soil Conf. New Zealand, 194: 3-6.

Dean, L. A. 1962. Applications of radioisotopes to the study of fertilizer usage: A critique. In Radioisotopes in Soil-Plant Nutrition Studies. Internatl. Atomic Energy Agency: p. 407-417.

Eck, H. V., and Fanning, Carl. 1962. Fertilization of dryland winter wheat under stubble-mulch and one-way tillage on Pullman silty clay loam. Texas Agr. Expt. Sta. Misc. Publ. 584, 3 pp.

Eck, H. V., and Ford, R. H. 1962. Restoring productivity on exposed subsoils. Jour. of Soil and Water Conserv. 17(6): 274-275.

Leamer, Ross W. 1963. Residual effects of phosphorus fertilizer in an irrigated rotation in the Southwest. Soil Sci. Soc. Amer. Proc. 27(1): 65-68.

Leggett, G. E., and Moodie, C. D. 1962. The aeration-recovery method for determining ammonium fixation by soils under moist conditions. Soil Sci. Soc. Amer. Proc. 26(2): 160-163.

MacKenzie, A. J., Spencer, W. F., Stockinger, K. R., and Krantz, B. A. 1963. Seasonal nitrate-nitrogen content of cotton petioles as affected by nitrogen application and its relationship to yield. Agron. Jour. 55: 55-59.

Olsen, S. R., Kemper, W. D., and Jackson, R. D. 1962. Phosphate diffusion to plant roots. Soil Sci. Soc. Amer. Proc. 26: 222-227.

Power, J. F., Grunes, D. L., Willis, W. O., and Reichman, G. A. 1963. High P levels cushion crops from temperatures. Crops and Soils 15: 21.

Ramig, R. E., and Rhoades, H. F. 1962. Nitrogen needs also depend on soil moisture. Crops and Soils 14(6): 24.

Ramig, R. E., and Rhoades, H. F. 1963. Interrelationships of soil moisture level at planting time and nitrogen fertilization on winter wheat production. Agron. Jour. 55(2): 123-217.

Robins, J. S., and Domingo, C. E. 1962. Moisture and nitrogen effects on irrigated spring wheat. Agron. Jour. 54(2): 135-138.

Robinson, R. R., Rhykerd, C. L., and Gross,C. F. 1962. Potassium uptake by orchardgrass as affected by time, frequency and rate of potassium fertilization. Agron. Jour. 54(4): 351-353.

Smika, D. E., Haas, H. J., and Rogler, G. A. 1963. Native grass and crested wheatgrass production as influenced by fertilizer placement and weed control. Jour. Range Management 16: 5-8.

Stanberry, C. O., and Anderson, D. M. 1962. A convenient punched-card filing system. Soil Sci. 94: 397-403.

Stanberry, C. O., Schreiber, H. A., Lowrey, M., and Jenson, C. L. 1963. Sweet corn production as affected by moisture and nitrogen variables. Agron. Jour. 55: 159-161.

Stewart, B. A., and Porter, L. K. 1963. Inability of the Kjeldahl method to fully measure indigenous fixed ammonium in some soils. Soil Sci. Soc. Amer. Proc. 27: 41-43.

Stockinger, K. R., and Schulback, H. 1962. Irrigation. In Cotton Production in the Lower Desert Valleys of California. Calif. Agr. Expt. Sta. Cir. 508, 113-115.

Vicente-Chandler, J., and Figarella, J. 1962. The effect of five nitrogen sources on yield and composition of Napier grass. Jour. Agr., Univ. of Puerto Rico 46(2): 102-105.

Vicente-Chandler, J., Pearson, R. W., Abruna, F., and Silva, S. 1962 Potassium fertilization of intensively managed grasses under humid tropical conditions. Agron. Jour. 54(5): 450-453.

Vicente-Chandler, J., Silva, S., and Figarella, J. 1962. Effect of frequency of application on response of Guineagrass to nitrogen fertilization. Jour. Agr., Univ. of Puerto Rico 46(4): 342-349.

Viets, Frank G., Jr. 1962. Fertilizers and efficient use of water. Advances in Agron. 14: 223-263.

Viets, Frank G., Jr. 1962. Chemistry and availability of micronutrients in soils. 1962. Jour. Agr. and Food Chem. 10: 174-178.

Welch, L. F., and Adams, W. E. 1963. Substituting nitrogen for acres. Georgia Agr. Res. 4(3): 8-9.

Welch, L. F., Adams, W. E., and Carmon, J. L. 1963. Yield response surfaces, isoquants, and economic fertilizer optima for Coastal Bermudagrass. Agron. Jour. 55: 63-67.

Soil Chemical Properties

Bower, C. A., Carlson, R., Dregne, H. E., Haise, H. R., Legg, J. O., Reeve, R. C., and Whitney, R. S. 1962. Soil salinity and irrigation in the Soviet Union, Report of the Technical Study Group: Agricultural Research Service, USDA, 41 pp.

Hassbroek, F. J., Noggle, JC, and Fleming, A. L. 1962. High-resolution autoradiography without loss of water-soluble ions. Nature 125: 615-616.

McNeal, B. L., and Young, J. L. 1963. Paper electrochromatography of clay minerals. Nature (London) 197: 1132.

Menzel, R. G. 1962. Decontamination of soils. Plant Food Review 8 (3): 8-12.

Pinck, L. A. 1962. Adsorption of proteins, enzymes, and antibiotics by montmorillonite. Clays and Clay Minerals 9: 520-529.

Tillage, Residue Management and Cropping Systems

Eagleman, J. R., and Jamison, V. C. 1961. The influence of soil textural stratification and compaction on moisture flow. Missouri Agr. Expt. Sta. Res. Bul. 784, 14 pp.

Free, G. R., and Bay, C. E. 1962. Excessive tillage not always harmful. Crops and Soils 14(6): 22-23.

Free, G. R., Fertig, S. N., and Bay, C. E. 1963. Zero tillage for corn following sod. Agron. Jour. 55: 207-208.

Greb, B. W., and Black, A. L. 1962. Sorghum residue reduction in a stubble mulch fallow system. Agron. Jour. 54(2): 116-119.

Haas, H. J. 1962. Fitting crops and crop sequences to available water. Internatl. Seminar, Water and Soil Utilization Proc. 8 pp. (mimeo).

Haas, H. J., and Willis, W. O. 1962. Moisture storage and use by dryland spring wheat cropping systems. Soil Sci. Soc. Amer. Proc. 26(5): 506-509.

Hauser, V. L., and Taylor, H. M. 1963. Deep tillage of high plains hard-land soils. Texas Agr. Prog. 9(2): 7-8.

Horning, T. R. 1963. Cloddy seedbeds halt erosion. Pacific Northwest Farm Quad. 86(6): 5.

Horning, T. R., and Oveson, M. M. 1962. Cloddy and conventional seedbeds for wheat production in the Northwest. Agron. Jour. 54(3): 229-232.

Horning, T. R., and Oveson, M. M. 1962. Cloddy seedbed saves both money and soil. Crops and Soils 14(9): 25.

Horning, T. R., and Oveson, M. M. 1962. Minimum tillage of winter wheat. USDA Agr. Res. 10(9): 8-9.

Horning, T. R., and Oveson, M. M. 1962. Stubble-mulching in the Northwest. USDA Agr. Inform. Bul. 253, 28 pp.

Knisel, W. G., Jr., Cox, M. B., and Tucker, B. B. 1961. Effect of land treatment on runoff at Cherokee, Oklahoma. Oklahoma Agr. Expt. Sta. Bul. 583, 22 pp.

Luebs, R. E. 1962. Investigations of cropping systems, tillage methods, and cultural practices for dryland farming at Fort Hays (Kansas) Branch Experiment Station. Kansas Agri. Expt. Sta. Bul. 449, 114 pp.

Lyles, L., and Woodruff, N. P. 1962. How moisture and tillage affect soil cloddiness for wind erosion control. Agric. Engin 43(3): 150-153.

Mazurak, A. P., and Ramig, R. E. 1962. Aggregation and Air-water permeabilities in a chernozem soil cropped to perennial grasses and fallow-grain. Soil Sci. 94(3): 151-157.

Miller, D. E., Bunger, Wm. C., and Proebsting, E. L., Jr. 1963. Properties of soil in orchard as influenced by travel and cover crop management systems. Agron. Jour. 55(2): 188-191.

Miller, D. E., and Kemper, W. D. 1962. Water stability of aggregates of two soils as influenced by incorporation of alfalfa. Agron. Jour. 54(6): 494-496.

Moody, J. E., Lillard, J. H., and Jones, J. N., Jr. 1962. Straw mulch will boost corn yield. Crops & Soils 14(8): 27.

Parker, D. T. 1962. Influence of mulching on the manganese content of corn plant tissue. Agron. Jour. 54: 303-305.

Parker, D. T., and Larson, W. E. 1962. Crop residue placement in corn and its effect upon growth of corn. Agron. Jour. 54: 263-267.

Rauzi, F., Lang, R. L., and Becker, C. F. 1962. Mechanical treatments on shortgrass rangeland. Wyo. Agr. Expt. Sta. Bul. 396, 16 pp.

Rumery, M. G. A., and Ramig, R. E. 1962. Irrigated sudangrass for dairy cows. Nebraska (Lincoln) Agr. Expt. Sta. Bul. 472, 12 pp.

Schaller, F. W., and Amemiya, M. 1962. What tillage for corn? Iowa Farm Sci. 16(10): 3-6.

Siddoway, F. H., and McKay, H. C. 1962. Tillage of sweet clover under dryland conditions. Idaho (Moscow) Agr. Ext. Service Bul. 388, 12 pp.

Soil and Water Conservation Research Division, Agricultural Research Service Committee, C. J. Whitfield, Chairman. 1962. A standardized procedure for residue sampling. USDA, ARS 41-68, 9 pp.

Taylor, H. M. 1962. Seedling emergence of wheat, grain sorghum, and guar as affected by rigidity and thickness of surface crusts. Soil Sci. Soc. Amer. Proc. 26(5): 431-433.

Taylor, H. M. 1962. Switchgrass emergence through nonporous soil sealing compounds. Agron. Jour. 54: 466-467.

Taylor, H. M., and Burnett, E. 1962. A report on plowpan--its causes, effects and cures. Soil and Water 11(2): 6-7.

Taylor, H. M., Burnett, E., and Welch, N. H. 1963. Cotton growth and yield as effected by taproot diameter within a simulated restraining soil layer. Agron. Jour. 55: 143-144.

Taylor, H. M., and Hauser, V. L. 1962. Deep plowing and vertical mulching boost water intake. Crops and Soils 15(2): 23.

Vicente-Chandler, J., and Figarella, J. 1962. Experiments on plantain production with conservation in the mountain region of Puerto Rico. Jour. Agr. Univ. Puerto Rico 46(3): 226-236.

White, A. W., Jr., Sparrow, G. N., and Carter, R. L. 1962. Peanuts and corn in sod-based rotations. Georgia Agr. Res. 4(2): 5-6.

Willis, W. O., and Carlson, C. W. 1962. Conservation of winter precipitation in the northern Plains. Jour. Soil & Water Conserv. 17(3): 122-123, 128.

Young, J. L. 1962. Inorganic soil nitrogen and carbon: Nitrogen ratios of some Pacific Northwest soils. Soil Sci. 93(6): 397-404.
Young, J. L., and Cattani, R. A. 1962. Mineral fixation of anhydrous NH_3 by air-dry soils. Soil Sci. Soc. Amer. Proc. 26: 147-152.

Soil Microbiology

Allison, F. E., and Klein, C. J. 1962. Rates of immobilization and release of nitrogen following additions of carbonaceous materials and nitrogen to soil. Soil Sci. 93: 383-386.
Allison, F. E., and Murphy, R. M. 1962. Comparative rates of decomposition in soil of wood and bark particles of several hardwood species. Soil Sci. Soc. Amer. Proc. 26: 463-466.
Clapp, C. E., Davis, R. J., and Waughaman, S. H. 1962. The effect of rhizobial polysaccharides on aggregate stability. Soil Sci. Soc. of Amer. Proc. 26: 466-469.
Clark, Francis, E., Jackson, Ray D., and Gardner, H. R. 1962. Measurement of microbial thermogenesis in soils. Soil Sci. Soc. Amer. Proc. 26: 155-160.
Davis, R. J. 1962. Resistance of rhizobia to antimicrobial agents. Jour. of Bact. 84(1): 187-188.
Davis, R. J. 1963. Viability and behavior of lyophilized cultures after storage for twenty-one years. Jour. of Bact. - Notes 85: 486-487.
Guenzi, W. D., and McCalla, T. M. 1962. Crop residues may retard germination. Crops and Soils 14(6): 19.
Guenzi, W. D., and McCalla, T. M. 1962. Inhibition of germination and seedling development by crop residues. Soil Sci. Soc. Amer. Proc. 26: 456-458.
MacKenzie, A. J. 1962. Chemical treatment of mineral deposits in drain tile. Jour. of Soil and Water Conserv. 17: 124-125.
McCalla, T. M. 1962. Micro-organisms and their activity in the soil. Soil Conservation 28(2): 36-37.
Menzies, J. D. 1963. Survival of microbial plant pathogens in soil. Botanical Review 29(1): 79-122.
Parker, D. T. 1962. Decomposition in the field of buried and surface-applied cornstalk residue. Soil Sci. Soc. Amer. Proc. 26: 559-562.
Parker, D. T., and Larson, W. E. 1962. Nitrification as affected by temperature and moisture content of mulched soils. Soil Sci. Soc. Amer. Proc. 26: 238-242.
Pinck, L. A., Soulides, D. A., and Allison, F. E. 1962. Antibiotics in soils: IV. Polypeptides and macrolides. Soil Sci. 94: 129-131.
Smith, J. H. 1963. A biosynthesis chamber for producing plants labeled with carbon-14. Atompraxis. 9 Heft 3, 73-75.
Smith J. H., Allison, F. E., and Mullins, J. F. 1962. Design and operation of a carbon-14 biosynthesis chamber. USDA Misc. Pub. 911, 15 pp.
Smith, J. H., Allison, F. E., and Soulides, D. A. 1962. Phosphobacterin as a soil inoculant. USDA Tech. Bul. No. 1263, 22 pp.
Soulides, D. A., Pinck, L. A., and Allison, F. E. 1962. Antibiotics in soils. V. Stability and balance of soil-adsorbed antibiotics. Soil Sci. 94: 239-244.

AREA 11: SOIL, WATER, AND PLANT RELATIONS AS THEY AFFECT USE OF LAND AND WATER RESOURCES

Problem. The interrelations between climate, soil, and plant growth must be understood before soil and water management practices can be developed that will beneficially use solar energy. Research data show that seldom is more than 2 percent of the solar energy received actually used by the plant in photosynthesis. Eighty percent of the energy received is used for evaporating some 2 billion acre feet of water from plants and soil each year. By comparison, total disappearance of water for municipal and industrial uses is only 14 million acre feet per year. This total energy cannot be altered, but it is possible that a greater percentage may be diverted to use for photosynthesis rather than for evaporation.

The use of water in the soil profile is dependant on the growth and proliferation of the roots, which act as pumps. There is a lack of knowledge concerning the operation and effectiveness of the roots which are provided by the plant as pumps.

USDA PROGRAM

The Division program in this area involves soil physicists, soil chemists, plant physiologists, and engineers in both basic and applied studies. Research to study the effect of physical properties of soil on the movement of water to and into plant roots is being done at Ithaca, New York; Urbana, Illinois; Columbus, Ohio; Fort Collins, Colorado; Manhattan, Kansas; Big Spring and Weslaco, Texas; Tempe, Arizona; and Riverside, California. Research concerned with the determination of plant-soil-meteorological interactions involved in the movement of water in plants and the exchange of water, heat, and carbon dioxide between plants and the atmosphere is being conducted at Ithaca, New York; Watkinsville, Georgia; Thorsby, Alabama; Morris, Minnesota; Urbana, Illinois; Weslaco and Bushland, Texas; Manhattan, Kansas; and Tempe, Arizona. Research for the development of soil and crop management practices for maximum energy conversion is being conducted at Ithaca, New York; Thorsby, Alabama; Morris, Minnesota; Urbana, Illinois; Bushland and Temple, Texas; Manhattan, Kansas; and Tempe, Arizona.

The Division scientific effort devoted to research in this area totals 28.5 professional man-years. Of this number, 14.5 are devoted to relation of the physical properties of the soil to the movement of water to and into plant roots; 11.0 to determination of plant-soil-meteorological interactions involved in the movement of water in plants and the exchange

of water, heat, and carbon dioxide between plants and the atmosphere; and 3.0 to development of soil and crop management practices for maximum energy conversion.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Relation of the Physical Properties of Soil to the Movement of Water to and into Plant Roots

1. Movement of moisture in soils. Studies conducted at the U. S. Water Conservation Laboratory, Tempe, Arizona, on the movement of tritiated water in unsaturated Pachappa loam soil showed that vapor diffusion plays a major role in water movement in drier soils. The maximum vapor diffusion occurred when the soil was at 4 percent moisture content. Above and below 4 percent moisture, the values decreased sharply. When the soil moisture was at the 4 percent moisture, the diffusion coefficient was three and a half times that at either 2 or 40 percent. These findings give a much better understanding of moisture movement in unsaturated soils. (SWC 11-gG1)

Laboratory studies at Logan, Utah, with temperature as a variable in the soil-plant-water system, indicated that nonequilibrium thermodynamics can provide a broad structure from which linear flow equations for the soil system may be developed including nonisothermal cases with moisture and osmotic gradients. Adsorption isotherms and heat of wetting measurements were made on water-kaolinite and water-Millville loam soil systems from which the integral thermodynamic quantities of entropy and enthalpy of the adsorbed water were calculated. The average internal energy of the adsorbed film was found to be lower than that of liquid water. The results of these basic studies add to our knowledge of the movement of water through air, soil, and plants. (SWC 11-13(g1))

Probably the least understood part of the hydrologic cycle is the redistribution of water in a soil after irrigation or rainfall. Because of the nonlinearity of the partial differential equation describing the water flow process and the hysteresis involved, exact analytical solutions seem out of the question. Moreover, sufficient data are not available to justify a numerical solution of the equation. An attempt to approximate the solution by analytical means has had some success. While the approximate solutions of the equation still leave much to be desired, they do provide a clearer understanding of the nature of this redistribution process and allow one to determine how the soil properties, the dimensions of the system, and the initial and boundary conditions influence the drainage of unsaturated soil. Experimental techniques have been devised at the U. S. Salinity Laboratory for testing mathematical relations on laboratory soil columns. If the tests confirm the validity of the equations, application can be made to several important soil and water management problems. With this information, it will be possible to more

precisely determine the amount of water needed in any given irrigation and will also make it possible to predict the amount of salts that will be moved from the soil profile by a given amount of water. (SWC 11-gF1)

At the U. S. Salinity Laboratory, the unsaturated conductivity and soil water diffusivity have been measured as a function of water content and soil suction at different temperatures. A very large temperature coefficient has been found for all soils studied when the suction was above one or two hundred millibars. The temperature coefficient for bulk water is not sufficient to explain this large effect. The data verify that water movement rates at low temperatures (just above freezing) may well limit availability of water to plants, even at relatively low suctions. (SWC 11-gF1)

2. New techniques for measuring moisture flow. At the U. S. Salinity Laboratory, several new techniques have been developed to use in characterizing the movement of water and water vapor through the soil and from soil surfaces. An automatic recording system has been developed for the shallow black pan evaporimeter which gives observations of rapid changes in evaporative conditions. A radial flow cell has been developed to characterize the movement and flow of moisture through undisturbed soil samples. (SWC 11-gF1)

An improved neutron probe to determine the moisture content of soil has been developed at Brawley using a Pu-Be source and a LiI (Eu activated) crystal. It is especially sensitive at low moisture contents, and allows more accurate counts to be made in a shorter time. At 20.5 percent moisture by volume, the improved scintillation probe gave 141,000 cpm. compared to 3,160 for the commonly used Nuclear-Chicago Ra-Be neutron probe. The sample radius and interface effects were similar for both probes. (SWC 11-13(g1))

A method was developed at Logan, Utah, to measure the relative humidity at the air-water interface during evaporation. Pure water and solutions containing three different concentrations of potassium chloride were allowed to evaporate into air from a porous plate under controlled thermal gradients. The observed reduction in evaporation rate induced by the KCl solution was then interpreted as the effect of salt concentration at the air-water interface and its effect on the vapor pressure of water. A flux equation was developed through which the effective vapor pressure at the air-water interface could be calculated. These findings have the potential to greatly advance our understanding of the drying process. (SWC 11-13(g1))

At Big Spring, Texas, a thermocouple psychrometer using a Peltier junction was constructed and procedures were developed for measuring soil water activity in the moisture range of availability to plants. The apparatus has proved to be very satisfactory when good temperature control is maintained. This technique has the advantage of covering the range

of soil moisture important to plant growth. Another advantage of the method is that the osmotic potential is also measured. It is hoped that after some additional laboratory evaluation, the equipment can be tested in the field. (SWC 11-e1)

At Urbana, Illinois, the research on both flow solutions and data collection has been very productive. Two transient, unsaturated flow solutions for one-dimensional cases have been completed and a third case involving water use by plants, soil evaporation and flow to plant roots is well underway. (SWC 11-c3)

The use of straingage pressure transducers and hydraulic switching in measurement of water tension has been developed to the point where field use is possible. Instrumentation of small watersheds is now possible. Considerable improvement has also been made in the use of gamma ray procedures for measuring water content in transient flow systems. The simultaneous measurement of water content and water tension in a horizontal flow system has shown conclusively that the content-tension function is unique for the flow system studied. (SWC 11-c3)

At Urbana, the measurement of water diffusivity has been studied by use of a cylindrical flow cell. It has been found there is a discontinuity in the water content-energy curve (when the direction of flow is changed) which produces a discontinuity in the diffusivity-water content function. (SWC 11-c3)

Also at Urbana, a low-cost weighing lysimeter, utilizing a tire tube filled with water as the weighing device, has been developed. The lysimeter offers considerable promise for obtaining water use measurements under field conditions because of its low cost. It should now be possible to evaluate soil moisture relations at a large number of field locations. (SWC 11-c1)

3. Water flow problems in drainage. At Columbus, Ohio, the solution of water flow problems for the drainage of sloping land has been completed. The solution indicated that the hydraulic conductivity of the backfill has a much greater influence on drain flux than altering the drain depth. Also at Ohio, a large block of soil was isolated for determination of the hydraulic conductivity. The values of conductivity obtained thereby were found to be more in line with those necessary to describe the functioning of a tile drainage system than were values obtained by other methods. (SWC 11-c3)

4. Loss and gain from a free water surface. At Weslaco, Texas, evaporation and condensation were studied as a function of water surface temperature, and ambient temperature and relative humidity conditions. Rates ranged from condensation at the rate of 1.6 cm. per day to evaporation at the rate of 4.4 cm. per day. The evaporation rate increased faster

with increasing water temperature than the vapor pressure of water itself. Raising the ambient relative humidity by 20 percent at a given air temperature reduced the evaporation and condensation rates by about 0.4 cm. water depth per day at all water temperatures (10°, 20°, 30°, 40°, and 50° C.). For a given ambient relative humidity and water temperature condition, the evaporation or condensation rate decreased by 0.3 to 0.6 cm. water depth per day with a 10° C. increase in room temperature. The evaporation and condensation rates correlated closely with the water vapor pressure difference between the water surface and the ambient air. (SWC 11-e1)

B. Determination of Plant-Soil-Meteorological Interactions Involved in the Movement of Water in Plants and the Exchange of Water, Heat, and Carbon Dioxide Between Plants and the Atmosphere

1. Vertical transfer of energy and gases. At Ithaca, New York, the mechanisms and rates of vertical transfer of matter and energy were studied in a dense stand of field corn. On the basis of measurements of radiation transmission and reflection, an incomplete model for the height distribution of photosynthesis and transpiration has been proposed. Potential photosynthesis and potential transpiration, defined with respect to availability of light and of total radiant energy, were found to have a nearly constant ratio with height. Shear stress and eddy viscosity decrease exponentially with depth into the plant stand, in the upper two-thirds of the stand. The concepts of mixing length and friction velocity--so useful in the earlier development of the micrometeorology of the air layer just above the crops--remain applicable in the more complex medium of the plant-air layer. Contrary to previous expectations, the autocorrelation analysis of a single, continuous wind-speed trace is not sufficient to yield reliable values of eddy viscosity. (SWC 11-a1)

A method has been developed for the statistical analysis of simultaneous wind speed and temperature profiles in the surface air layer (above the vegetation). A test set of the best available data has been analyzed according to this method. With the present concentration on the plant-air layer in the Ithaca studies, the method will not find its best application there. (SWC 11-a1)

The transport of energy away from the earth's surface is accomplished by the action of wind. The rate at which a given quantity is transferred is a function of the wind speed. Thus, if wind speed is reduced, transport should be reduced within certain limitations. At Morris, Minnesota, evaluation of the effect of a living windbreak (i.e., corn rows planted within a sugar beet field) has shown that wind speed from the south can be reduced by as much as 50 percent. If the energy budget is altered along with the transport system, the practice could prove to be an effective water conservation practice. (SWC 11-c2)

There is some indication that at low wind speeds, the transport of CO_2 down into the crop canopy may limit carbon dioxide fixation by plants. At Urbana, Illinois, a field test was initiated in which wind machines were used to maintain air flow in the crop canopy. The increased air flow did not alter crop yields. (SWC 11-c1)

Diurnal patterns of carbon dioxide concentrations at the top of the corn crop were obtained at Ithaca, New York, in 1962. Usually, there is a buildup of carbon dioxide during the night to 400-500 ppm. and a decrease to under 300 ppm. in the morning. The night time accumulation of carbon dioxide near the ground is less marked if the wind speed holds up during the night. (SWC 11-a1)

2. Net radiation as influenced by soil moisture and tillage. At Manhattan, Kansas, laboratory measurements of radiant energy reflected from soils at different moisture contents showed that as moisture content increased, reflection decreased. The curves were logarithmic in form with but one exception, and each soil had its own unique curve. The precision of the curves was sufficient for most of the soils to suggest that rapid determination of soil moisture may be feasible by the measurement of reflected radiant energy. (SWC 11-e1)

The effect of tillage treatments on net radiation was also studied at Manhattan. The tillage treatments were: (1) unplowed, (2) plowed, (3) plowed, disked, (4) plowed, disked, harrowed, and (5) plowed, disked, harrowed, and rolled with a lawn roller. When the soil was dry, the tillage treatments had a significant effect on net radiation. The plowed and rolled treatments differed at the 0.01 level from each other and from the other treatments. The other treatments were not significantly different from one another. The average net radiation difference between the plowed and rolled treatments was 0.11 cal./cm.^{2}/min., or enough energy to evaporate 0.1 cm. water during the course of a day. When the soil was wet, net radiation measurements did not differ significantly among the tillage treatments. (SWC 11-e1)

3. Equipment to measure the water content of plant leaves. Equipment and procedures were developed and tested at the U. S. Water Conservation Laboratory, Tempe, Arizona, for using beta radiation to rapidly and accurately measure changes in the water content of plant leaves without damaging the plants. Previous methods for making this measurement required destruction of the plant leaf and upset the balance of the plant water transport system. This new development will permit continuous measurements of the water balance of undisturbed plants in the laboratory and in the field, which will be of great value in studying the mechanisms governing the use of water by plants. The equipment can be made lightweight and readily portable, which leads to an immediate application in measuring plant moisture stress for determining when irrigation is required. (SWC 11-gG1)

4. Transpiration as influenced by plant and soil factors. At Watkinsville, Georgia, radiant energy, vapor pressure deficits, plant size, and plant age accounted for 90 percent of the variation in transpiration by corn plants in a controlled climate room. Soil moisture stress effectively stopped photosynthesis. Transpiration rates were influenced by the root and leaf area ratio and by soil and root ratio. (SWC 11-b2)

The rate of water loss by plants as influenced by leaf epidermal hairs has been studied at Urbana, Illinois. By using a shaving technique to remove epidermal hairs, it has been found that corn and soybean epidermal hairs may have a significant role in retarding transpiration (as much as 10 percent), and that this effect may be due to interference with air movement. (SWC 11-c1)

Studies in a controlled climate chamber at the U. S. Water Conservation Laboratory, Tempe, Arizona, showed that moderately wilted cotton plants recovered at a more rapid rate than plants which were only slightly wilted. Sudden exposure of the plants to light caused evaporation of water from the leaves to exceed uptake by the roots and wilting resulted. About 30 minutes after initial wilting, uptake by roots began to exceed evaporation from leaves and the plants began to recover. The degree of wilting was dependant upon the dryness of the air (vapor pressure deficit). Drier air caused greater initial wilting, but also resulted in more rapid recovery. (SWC 11-gG1)

5. Influence of moisture stress on plant turgidity. Relative turgidity measurement to indicate moisture stress within the cotton plant was a good criterion for irrigation timing in both 1961 and 1962 at Weslaco, Texas. The cotton plant exhibits visible symptoms of wilt at 68-70 percent relative turgidity, but it can withstand short periods of rather severe plant moisture stress (66 percent relative turgidity) during the bloom stage--the critical stage of plant growth--without significant reductions in yield. Long periods of severe to moderately severe plant moisture stress (66 to 70 percent relative turgidity) during the bloom stage caused significant reductions in yield. There were no significant reductions in cotton yields as long as the average relative turgidity of the plant was 72 percent or higher during the 20 to 6-week period following first bloom. A multiple regression analysis of the 1961 data revealed that 88 percent of the variation in relative turgidity of the cotton plant was accounted for by soil moisture (first foot), ambient temperature (at times of sampling), and pan evaporation (average of sampling day and day before). Soil moisture had more than twice as much influence on relative turgidity of cotton as did ambient temperature and more than three times as much influence as did pan evaporation. The relative turgidity technique is indicated to be much superior to soil sampling for determining irrigation timing. (SWC 11-e1)

6. Influence of depth of water table on the evapotranspiration rate. At Weslaco, Texas, cotton was grown in lysimeters in which water tables of two different salt concentrations were maintained at 3, 6, and 9 feet. Total moisture use (evapotranspiration) consisted of (a) the water used from the water table, (b) moisture depleted from the soil above the water table, and (c) rainfall. Moisture condition in the root zone and the water table depth influenced the proportion of the total moisture used from the water table. From the first bloom to first picking stage of maturity, approximately 60, 40, and 20 percent of the total water use was from the 3-, 6-, and 9-foot-deep water tables under low soil moisture conditions. Under high soil moisture conditions, approximately 40, 25, and 10 percent of the total water use was from the 3-, 6-, and 9-foot-deep water tables. The proportion of the total use from the water table was the same for both salt concentrations (electrical conductivities 11 to 13 mmhos./cm. and 5 to 7 mmhos./cm.), but the higher salt concentration did significantly reduce the total moisture use of cotton. Water table depth did not significantly affect total moisture use. Differences in cotton yields due to moisture condition, water table depth, or salt concentration were not significant at the 5 percent level. (SWC 11-e1)

7. Crop performance as influenced by leaf area. Tobacco studies at Florence, South Carolina, have shown that leaf area indices and yields increased as plant spacings decreased and nitrogen rates increased. The quality of tobacco, however, was much higher with a low nitrogen rate. (SWC 11-b2)

At Thorsby, Alabama, an investigation of leaf growth in cotton plants has led to development of a method of leaf area determination. An equation was obtained which gives an accurate estimate of leaf area regardless of the variety used. A high degree of correlation was found between leaf area and leaf dry weight. In late August, a linear relationship still exists between dry matter and leaf area per acre, indicating that more leaf area could have been used in photosynthesis. The results show clearly the importance of obtaining a large leaf area by the middle of July for maximum cotton yields. (SWC 11-b1)

C. Development of Soil and Crop Management Practices for Maximum Energy Conversion

1. Influence of topping and pruning cotton on yields and quality of cotton. Studies at Thorsby, Alabama, show that topping cotton plants at either 36-, 42-, or 48-inch heights increased the yield and quality of cotton and decreased the amount of lodging and boll rot. A combination of pruning side branches and topping of the cotton plants reduced the amount of boll rot more than when plants were topped only. (SWC 11-b1)

2. Transpiration as influenced by various compounds. The work with hexadecanol as a transpiration suppressant at Urbana, Illinois, has shown that no beneficial effect resulted. Several other compounds known to cause stomatal closure have been tested. Results show that all compounds were toxic at the concentration required to produce an effect on transpiration. (SWC 11-c1)

Several antitranspirants were studied at Watkinsville, Georgia. Two compounds did reduce the transpiration rate of bean plants, but the others were phytotoxic. These results suggest that these materials may have some use in transplanting nursery stock, but cannot be recommended for field application to agronomic crops. (SWC 11-b2)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Relation of the Physical Properties of Soil to the Movement of Water To and Into the Plant Root

Cary, J. W. 1963. Onsager's relation and the non-isothermal diffusion of water vapor. Jour. Phys. Chem. 67: 126-129.

Cary, J. W., and Taylor, S. A. 1962. The interaction of the simultaneous diffusions of heat and water vapor. Soil Sci. Soc. Amer. Proc. 26: 413-416.

Cary, J. W., and Taylor, S. A. 1962. Thermally driven liquid and vapor phase transfer of water and energy in soil. Soil Sci. Soc. Amer. Proc. 26:417-420.

Clark, Francis E., Jackson, Ray D., and Gardner, Herbert R. 1962. Measurement of microbial thermogenesis in soil. Soil Sci. Soc. Amer. Proc. 26(2): 155-160.

Covey, Winton. 1963. Mathematical study of the first stage of drying of a moist soil. Soil Sci. Soc. Amer. Proc. 27(2): 130-134.

Covey, Winton, and Bloodworth, M. E. 1962. Mathematical study of the flow of water to plant roots. Texas Agr. Expt. Sta. Report MP-599, 15 pp. College Station, Texas.

Covey, Winton, and Lemon, E. R. 1962. Soil aeration and plant root relations. IV. Testing the cylindrical shell model in the transient case. Soil Sci. Soc. Amer. Proc. 26: 526-530.

Erie, Leonard J., and French, Orrin F. 1962. Safflower-Irrigate intelligently! Arizona Farmer-Ranchman 41(7): 6.

Erie, Leonard J., French, Orrin F., and Patterson, Lloyd L. 1962. Water management on DPL. Arizona Farmer-Ranchman 41(11): 12-13.

Gardner, W. R. 1962. Approximate solution of a non-steady-state drainage problem. Soil Sci. Soc. Amer. Proc. 26: 129-132.

Gardner, W. R. 1962. Note on the separation and solution of diffusion type equations. Soil Sci. Soc. Amer. Proc. 26: 404.

Klute, A., and Gardner, W. R. 1962. Tensiometer response time. Soil Sci. 93: 204-207.

Lemon, E. R. 1962. Soil Aeration and plant root relations. I. Theory. Agron. Jour. 54: 167-170.

Lemon, E. R., and Wiegand, C. L. 1962. Soil aeration and plant root relations. II. Root respiration. Agron. Jour. 54: 171-175.

Miller, D. E., and Kemper, W. D. 1962. Water stability of aggregates of two soils as influenced by incorporation of alfalfa. Agron. Jour. 54: 494-496.

Myers, L. E., and van Bavel, C. H. M. 1962. Measurement and evaluation of water table elevations. Proc. 5th Cong. of Internatl. Comm. of Irrig. and Drainage, Tokyo, Japan: 109-119.

Olsen, S. R., Kemper, W. D., and Jackson, R. D. 1962. Phosphate diffusion to plant roots. Soil Sci. Soc. Amer. Proc. 26(3): 222-227.

Qayyum, M. A., and Kemper, W. D. 1962. Salt-concentration gradients in soils and their effects on moisture movement and evaporation. Soil Sci. 93: 333-342.
Richards, L. A. 1960. Advances in soil physics. Internl. Soc. of Soil Sci. VII Cong. Tran. 1(1): 67-99.
Richards, L. A., and Ogata, Gen. 1960. Vapor pressure depression at a tensiometer cup. Internl. Soc. of Soil Sci. VII Cong. Trans. 1(1): 279-283.
Richards, L. A., and Richards, P. L. 1962. Radial-flow cell for soil-water measurements. Soil Sci. Soc. Amer. Proc. 26: 515-518.
Scott, E. J., and Hanks, R. J. 1962. Solution of the one-dimensional diffusion equation for exponential and linear diffusivity functions by power series applied to moisture flow in soils. Soil Sci. 94: 314-322.
Scott, E. J., Hanks, R. J., Peters, D. B., and Klute, A. 1962. Power series solutions of the one-dimensional flow equation for exponential and linear diffusivity functions. USDA ARS 41-64.
Thiel, T. J., Vimoke, B. S., and Taylor, G. S. 1962. Instrumentation and fabrication of an electrical resistance network for studying moisture flow problems. Jour. of Agric. Engin. Res. (British) 8: 323-327.
Vimoke, B. S., and Taylor, G. S. 1962. Simulating water flow in soil with an electrical resistance network. USDA ARS 41-65.

Determination of Plant-Soil-Meteorological Interactions Involved in the Movement of Water in Plants and the Exchange of Water, Heat, and Carbon Dioxide between Plants and the Atmosphere

Adams, John E. 1962. Effect of soil temperature on grain sorghum growth and yield. Agron. Jour. 54: 257-261.
Elkins, C. B., Jr., and Williams, G. G. 1962. Still and time-lapse photography of plant stomata. Crop Sci. 2: 164-166.
Erie, Leonard J. 1963. Irrigation management for optimum cotton production. Beltwide Cotton Prod. Mech. Conf. Proc. 64(2): 30-32.
Shinn, Joseph. 1962. Hot, dry days cut corn growth, but moisture high. Note in Crops and Soils 14(8): 27.
Tanner, C. B., and Lemon, E. R. 1962. Radiant energy utilized in evapotranspiration. Agron. Jour. 54: 207-212.
Thomas, J. R., Army, T. J., and Cox, E. L. 1962. Relationship of soil moisture and precipitation to spring wheat yields in the Northern Great Plains. USDA Production Research Report No. 56.
Woolley, Joseph T. 1962. Potato tuber tissue respiration and ventilation. Plant Physiol. 37: 793-798.

Development of Soil and Crop Management Practices for Maximum Energy Conversion

Peters, D. B., and Roberts, W. J. 1963. Use of octa-hexadecanol as a transpiration suppressant. Agron. Jour. 55: 79.

Woolley, Joseph T. 1962. Soil-applied hexadecanol as an evapotranspiration suppressant. Jour. of Soil & Water Conserv. 17: 130.

AREA 12: NUTRITION OF ANIMALS AS AFFECTED BY PROPERTIES AND CHARACTERISTICS OF SOILS AND PLANTS

Problem. For a long time, men have been concerned with and puzzled by the effect of soils upon the nutritional quality of crops. It was not until the development of the sciences of chemistry and nutrition that the reasons for the peculiar regional distribution of certain maladies of humans and animals could be understood.

The mineral nutrient chain from the soil to the plant to the animal works fairly well, but in some instances, the chain does not function properly. When there is a malfunction, livestock nutritional problems develop. The laboratory has prepared a map which shows that there are only seven states where mineral nutritional diseases in animals have not been recorded.

In many cases, lack of a basic understanding of the synthesis and metabolism of nutritionally important substances in plants and animals prevents progress. A knowledge of the functions and pathways of element transport through the food chain from soil to plant to animal is needed. The relationships among soil properties, both natural and as modified by treatment, climatic factors, and the nutritional quality of plants as measured chemically or by feeding test animals is required to enable farmers to select economic combinations of soil, crop, and livestock management practices that will meet human nutritional needs.

USDA PROGRAM

The Division program in this area involves soil scientists, biochemists and a plant physiologist at the U. S. Plant, Soil and Nutrition Laboratory, a U. S. D. A. laboratory located on the campus of Cornell University. Problems in animal nutrition that are prevalent in specific regions are investigated through field surveys in which the incidence of the nutritional problem is related to the composition of forages, types of soil, and other environmental factors. Investigations are directed toward understanding the functioning of micronutrients in the animal, and the mechanisms involved in the interactions between micronutrients in animal nutrition. The processes involved in the synthesis and breakdown of nutritionally important compounds in plants and animals are under investigation. One phase of these studies is directed toward the mechanism of formation and metabolism of amino acids and related compounds in plants, with special attention being directed toward the sulfur-containing amino acids. Another phase of this work is concerned with the mechanisms whereby amino acids are linked together to form protein, and the relationship between the molecular structure and the biological function of some of the compounds that play important roles in protein synthesis.

Studies involving large animals are conducted through contracts with State Agricultural Experiment Stations. Work on the causes of congenital malformations in livestock is conducted in cooperation with the Animal Disease and Parasite Research Division at Logan, Utah.

The Division scientific effort devoted to research in this area totals 12 professional man-years. Of this total, 3.6 are working on soil and plant composition as factors affecting the distribution of nutritional problems in livestock; 2.4 man-years are devoted to trace element functions and interactions in animal nutrition; 5.0 to biosynthesis of amino acids, peptides, and proteins; and 1.0 to chemistry of micronutrients in soils. The Soil Conservation Service maintains a full-time scientist at the Plant, Soil and Nutrition Laboratory for studies relating nutritional problems to specific kinds of soil.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Soil and Plant Composition as Factors Affecting the Distribution of Nutritional Problems in Livestock

A survey of factors associated with the geographic distribution of white muscle disease (muscular dystrophy) in livestock has been conducted. Inasmuch as it has been shown that this disease can be prevented by the addition of very small amounts of selenium to the livestock ration, emphasis was placed upon the Se content of soils and plants. In cooperation with O. H. Muth of Oregon State University, a map of the United States has been prepared showing locations where white muscle disease has occurred, locations where plants containing toxic quantities of Se have been collected, and the probable distribution of Se in soil parent materials. Information on the distribution of white muscle disease was compiled from contacts with State Veterinarians. The map shows that white muscle disease is very rare in regions where the soil parent material can be expected to contain Se coming from the seleniferous Cretaceous sediments of West-Central United States. White muscle disease is common to the south and east of the Great Lakes and in areas of the Pacific Northwest where the soils are formed on young volcanic materials. (SWC 12-aA3)

The Se content of forages from areas where white muscle disease has occurred is uniformly low. Samples collected in western New York, central Oregon and the Carson Valley of Nevada all contained less than 0.1 ppm. of Se. On the other hand, samples from western Iowa, Nebraska, western Minnesota and Missouri, where white muscle disease is rare, contained from 0.15 to 0.8 ppm. of Se. This phase of the Se work may be summarized as follows: First, there is a definite relationship between the Se content of forages and the incidence of white muscle disease. Second, all of the forage samples from areas where white muscle disease has been found contain less than about 0.1 ppm. of Se. These results

suggest that the use of selenized fertilizers to increase the Se content of forages may be a potential method for the prevention of white muscle disease. Furthermore, if selenized fertilizers should prove to be useful, they could be used generally in "white muscle disease" regions without danger of inadvertent use on soils that are currently producing plants having Se contents close to the lower limit of toxic Se concentration. On the basis of previous U. S. D. A. and State Experiment Station studies, this lower limit of toxic concentration of Se in feeds can be set at about 5.0 ppm. In order to investigate further the possibility for use of selenized fertilizers, evaluation of two experimental selenized fertilizers is under way in cooperation with the U. S. Fertilizer Laboratory at Beltsville, Md. (SWC 12-aA3)

The effect of soil application of Se upon the Se content of forages and on the incidence of white muscle disease in sheep fed on these forages is being studied in a field experiment conducted by means of a research contract with Oregon State University. Analysis of preharvest samples of the forages indicate that the soil treatment with Se resulted in forages containing from 0.1 to 0.3 ppm. of Se, which is above tentative limits for the animal's requirements and below the minimum toxic concentration. These forages are currently being fed to sheep at Corvallis, Oregon. (SWC 12-aA3)

In earlier work, it was reported that the plant Veratrum Californicum is the causative factor in Cyclopia (monkey face) in sheep. Samples of Veratrum collected from several sites, in cooperation with Dr. Wayne Binns of the A. D. P. Division, were compared for an effect on gestation in the rat. A level of 2.5% in the diet was selected as being the amount of the most toxic sample acceptable to the rat by a prior feeding trial. Five samples from various sites in Utah and Idaho were fed ad libitum at 2.5% during days four through thirteen after mating. Two out of six rats receiving a sample from Box Elder County, Utah, and one out of six fed a sample from Custer County, Idaho were found to be non-gravid at the end of gestation. However, at a 10% level in the diet, the Custer County, Idaho sample failed to have any effect on gestation. The other samples were without effect, and the diets containing them were consumed by the rats in an amount comparable to the basal diet. (SWC 12-aA3)

In a second experiment, the alcohol extract, the water extract, and the residue after extraction of the sample from Box Elder County, Utah, fed as addition to the basal diet, failed to have any effect on gestation in the rat. The extracts and the residue were prepared by Dr. Keeler of the National Animal Disease Laboratory. It was interesting to note that the residues fed at a level corresponding to unextracted Veratrum at 2.5% were as acceptable to the rat as was the basal diet. (SWC 12-aA3)

In addition to the above experiments, an attempt was made to increase the amount of Veratrum received by the rat, and in addition to shorten the length of time the animal would be receiving the Veratrum. By including the Veratrum in the diet fed ad libitum, the rat is able to limit the amount of Veratrum ingested so that she may not receive an amount sufficient to produce the desired toxicity. The new technique involves the administration of a predetermined amount of Veratrum by stomach tube at a time in gestation when the effect should be the greatest on the developing embryo. By using this technique and administering the Veratrum around days nine and ten of gestation, a considerable number of resorptions were found to be induced. (SWC 12-aA3)

Although this approach was merely carried out on an explorative basis, the results obtained were sufficiently encouraging to warrant a follow-up experiment using this technique.

In 1962, a study of micronutrient contents in forage plants in relation to important Oregon soils was initiated, in cooperation with the Oregon Agricultural Experiment Station and the Soil Conservation Service. The study was undertaken to clarify the various reports of malnutrition in livestock grazed in parts of Oregon and to delineate the occurrence of problem areas according to soils or geologic materials. Lithologic materials concerned are primarily basalt and surficial deposits of volcanic ash, pumice, diatomite and mixed alluvium derived from these and other materials. Organic soils are also included in the study. Nearly 480 forage samples and 180 soil samples of Ap horizons are currently being studied in the laboratory for cobalt, copper, molybdenum and sulfur. (SWC 12-aA1)

A report on the study of Co-deficient areas of the New England States has been submitted to the participating scientists for review. Their comments will be incorporated in a final report. The results of this study show two broad areas of Co-deficient soils in New England: (a) an area extending from the Saco River in southwestern Maine to the Merrimac River in eastern New Hampshire, and (b) a general area in southeastern Massachusetts from Boston southwest to Rhode Island and east to include Cape Cod. The Co-deficient soils in the two areas are Podzol, Brown Podzolic and Ground-Water Podzol, with surface horizon (A_p) textures of sand to fine sandy loam. In the two areas, these sandy soils have less than 5 ppm. total Co and grow red clover with less than 0.07 ppm. Co. Silt loam to clay soils in these areas have adequate amounts of Co to produce legumes with 0.10 ppm. or more Co, an amount which is adequate for grazing animals. (SWC 12-aA2)

The Co-deficient sandy soils in Maine and New Hampshire result primarily from the low Co contents inherited in the glacial drift derived from the granites of the White Mountains. The generally low Co contents in granitic materials from the White Mountains are also evident in the Co

contents of Alluvial soils. Alluvial soils formed on alluvium of the White Mountain drainage system have less Co than do comparable soils from alluvium of other drainage systems of the New England States. (SWC 12-aA1)

The Co-deficient sandy soils in southeastern Massachusetts appear related to drift derived locally from Dedham granodiorite. The mixing of the drift with marine sands along the coast and on Cape Cod could be an important factor in the low soil Co contents in this area. (SWC 12-aA1)

In the work in New England, about 60% of all grass samples collected contained less than 0.04 ppm. Co. This generally low Co content in grasses could account for some of the ill-defined distribution patterns of reported Co deficiency in the New England States. (SWC 12-aA2)

A greenhouse experiment designed to measure the effects of soil moisture levels upon plant uptake of Mo, Co and Cu has been completed. The concentration of Mo in the soil solution, and the uptake of Mo by alsike clover, were higher for soils maintained at a high moisture level than for the same soils maintained at a low moisture level. The effects of increasing soil moisture content upon the plant uptake of Co and Cu varied among the different soils used in the experiment. The results emphasize the need to investigate plants growing on poorly drained soils in areas where Mo toxicity to livestock is suspected. They also indicate that differences in seasonal rainfall may cause differences in the Mo content of forage plants. (SWC 12-aA2)

For the current year, work on the effects of nitrate fertilization on the nutritional quality of Coastal Bermuda hay is confined to feeding trials being conducted by the Animal Husbandry Department of the University of Georgia. These trials are designed to study interaction between nitrate level in the hay and vitamin A metabolism in the animal. (SWC 12-aA6)

B. Trace Element Functions and Interactions in Animal Nutrition

In addition to the continuing studies on the role of trace minerals in bone formation, some attention has been given to a study of mineral mixtures used to supplement purified diets. This research has resulted in a better understanding of the chloride nutrition of the young chick. (SWC 12-aA8)

Research indicated that observed differences in mineral mixtures could be attributed to the Cl content of these mixtures in combination with the Cl supplied by other dietary ingredients. A source of Cl which must be given consideration is that supplied by the amino acid hydrochlorides which are frequently used to supplement purified diets. It was found that the total Cl content of the diet should not exceed 0.60%.

Further experimentation indicated that the growth-depressing effects of excess Cl could be overcome by threefold increases in the sodium and potassium content of the diet. (SWC 12-aA8)

In addition to the studies on Cl tolerance, experiments were also conducted to ascertain the Cl requirement of the young chick. This was found to be approximately 0.14% of the diet. Chloride deficiency was characterized by extremely poor growth rate, dehydration, hemoconcentration, excessive mortality and a lowered blood Cl. In addition, deficient chicks exhibited rather specific nervous symptoms. (SWC 12-aA8)

Possible interactions with other minerals were also investigated. Alterations in levels of Na and K did not affect the growth rate of Cl-deficient chicks, but high levels of these elements did increase the incidence of nervous symptoms and mortality. Fluoride had no effect upon the course of Cl deficiency, but bromide was partially effective in alleviating some of the symptoms of this deficiency. At the levels fed, iodide depressed growth rate and produced nervous symptoms similar to those observed with Cl deficiency. The level of Cl did not influence the growth-depressing effects of I, but did alter the occurrence of nervous symptoms and mortality. (SWC 12-aA8)

Research on bone formation has been expanded to include an investigation of a rickets-like syndrome. Although gross examination suggests a cartilage abnormality similar to rickets, the histrological appearance differs considerably from the observed with hypovitaminosis D. This abnormality occurs in 20-30% of the chicks fed a purified diet which is thought to be adequate in all known nutrients. The occurrence does not appear to be influenced by the calcium, phosphorus or vitamin D content of the diet. However, the incidence is very low in chicks fed a commercial chick starter, suggesting that the problem has a nutritional origin. (SWC 12-aA8)

To date, the low incidence of this abnormality has made the problem very difficult to study experimentally. However, two recent findings will aid future research dealing with this problem. First, the use of pedigreed chicks has indicated that the occurrence of this syndrome can be influenced by heredity. Some matings produce offspring with 100% incidence, while other matings result in offspring free of this abnormality. Secondly, it has been found that slightly toxic levels of F will enhance the occurrence of the abnormality, although the problem itself does not seem to be related to F toxicity. (SWC 12-aA8)

The importance of copper in the nutrition of both plants and animals has long been known. Copper deficiency among grazing animals has been recognized, and associated with various areas throughout the world, for many years. It has frequently been impossible to correlate the Cu status of the grazing animal with the level of Cu in its forage, however.

Several factors which have been shown to influence Cu nutrition have been studied for some years at this laboratory under controlled conditions using the laboratory animal. It is well known that dietary Mo will increase the animal's Cu requirement. It has also been shown that sulfate intensifies this Mo-Cu interrelationship in grazing animals. Work at this laboratory, previously reported, has shown that dietary SO_4 may either accentuate or alleviate Mo toxicity in the laboratory animal, depending upon the Cu status of the animal. When Mo is fed to Cu-depleted animals, dietary SO_4 intensifies the toxic effect of Mo; if the animal has adequate Cu, SO_4 will correct the molybdenosis. (SWC 12-aA8)

The observation has often been made that the Cu nutrition of an animal does not always reflect the level of Cu in its diet. The level of Cu in the liver of the animal has generally been regarded as a relatively good index of the Cu status of the animal. This has not always been true, however. Molybdenum and SO_4 are two known factors which have been shown to affect tissue levels of Cu, but it is also evident that these are not the only ones. (SWC 12-aA8)

Studies of these factors which affect the Cu nutrition and the Cu stores of the animal are being continued. (SWC 12-aA7)

C. Biosynthesis of Amino Acids, Peptides and Proteins

In cooperation with the Department of Biochemistry of Cornell University, studies of the intermediate chemical processes in the biosynthesis of proteins have been continued. The work has been centered on investigations of the soluble ribonucleic acids (RNAs) that transfer activated amino acids to the "template" where protein synthesis takes place. The specific objective of the work is to determine the structures of the three soluble RNAs that were first purified in this laboratory last year. These are the alanine-, tyrosine-, and valine-specific soluble RNAs. Each of these RNAs is composed of approximately 80 nucleotide units coupled together in a long polynucleotide chain, and the problem is to establish the nature and sequence of the nucleotide units. Because of the complexity of the undertaking, it is anticipated that the problem will take a number of years. (SWC 12-aA4)

The major features of the nucleotide compositions of the RNAs were determined last year by ion exchange chromatography of alkaline hydrolyzates, but the procedure did not separate certain of the "trace" or "odd" nucleotides from adenylic acid, cytidylic acid, guanylic acid and uridylic acid, the major nucleotide components. During this year, a procedure was developed for separation and quantitative determination of the "odd" nucleotides. This procedure, which involves two-dimensional paper chromatography of an alkaline hydrolyzate, has been applied to the three purified RNAs. It was found that the alanine-RNA contains dimethylguanylic acid, inosinic acid, pseudouridylic acid and thymidylic acid, in addition

to the four major nucleotides. The tyrosine-RNA contains dimethyladenylic acid, dimethylguanylic acid, methyladenylic acid, methylguanylic acid, pseudouridylic acid and thymidylic acid. The valine-RNA contains dimethylguanylic acid, inosinic acid, methyladenylic acid, methylcytidylic acid, pseudouridylic acid and thymidylic acid. (SWC 12-aA4)

The most promising approach to the determination of the sequence of the nucleotides in the polynucleotide chain is to break the long chain into smaller fragments, determine the structures of these fragments, and then in some way determine the order in which the fragments occur in the original polynucleotide chain. By using different hydrolytic enzymes to break the nucleic acid chains at different specific nucleotides, one will obtain different sets of fragments, a set from each of the different enzymes. If a sufficient number of fragments are obtained so that one set of fragments overlaps another set, the complete sequence can be deduced. Investigations of this sort have been initiated. (SWC 12-aA4)

Pancreatic ribonuclease is known to cleave RNA molecules wherever pyrimidine nucleotides occur. This enzyme has been used to degrade the three purified RNAs, and much work has been done on the identification of the fragments. Ten dinucleotide, six trinucleotide and two tetranucleotide fragments of the alanine-RNA have been isolated and their compositions determined. The same type of results has been obtained with the other two RNAs. (SWC 12-aA4)

Takadiastase ribonuclease T1 splits RNAs specifically at guanylic acid. This ribonuclease has been isolated from takadiastase, and studies of digests of the RNAs by the enzyme are underway. A number of di-, tri- and tetranucleotides have been isolated. (SWC 12-aA4)

Before the complete nucleotide sequences of the RNAs are determined, many new procedures for sequence determination will be needed. In the development of new methods, the availability of relatively large amounts of purified RNAs will be of great value. Much has been done to increase large-scale preparation of the three purified RNAs. (SWC 12-aA4)

In collaboration with scientists at Purdue University, the soluble RNAs of Escherichia coli were fractionated by countercurrent distribution, and two different leucine-acceptor RNAs were isolated. The coding properties of these were tested in a cell-free system. It was found that one RNA led to incorporation of radioactive leucine into protein in the presence of poly UC, and the other RNA to incorporation in the presence of poly UG. The soluble RNAs are therefore the basis of the observed "degeneracy" of the amino acid code. (SWC 12-aA4)

Work of the past year has continued previous investigations of the nitrogen and sulfur compounds in plants with respect to their occurrence and metabolism. In previous years, several γ-glutamyl peptides were

isolated from plants. These are present in relatively high levels in the plant. They also have a close structural relation to some toxic principles of plants. Evidence for an enzyme responsible for the synthesis of these peptides was previously reported from this laboratory. Further work has continued to see whether this same enzyme (γ-glutamyl transpeptidase) may be responsible for hydrolysis of the peptides. The transpeptidase preparation from beans, which has hydrolytic activity as well as amino acid transferring activity, was tested to see how well these two activities are correlated. It was found that the ratio of amino acid transfer activity to hydrolytic activity was the same through several different purification steps and throughout its entire pH range. These results indicate that one enzyme is responsible for both formation and breakdown of γ-glutamyl peptides. (SWC 12-aA7)

A study of the contents of γ-glutamyl peptides and amino acids in Wedgewood iris, at different stages of growth, has been used as a tool to learn more about the physiological roles of these compounds in the plant. Two unknown peptides have been observed in leaves but not in bulbs. All previous γ-glutamyl peptides had been found in storage organs (bulbs and seeds) and decreased on germination. These two new unknown peptides increased on germination and were highest in the leaves. These peptides have been isolated from iris leaves. The one present in larger amount was obtained in crystalline form and has been identified as γ-glutamyl-L-alanine. The second peptide has been obtained in crystalline form and is probably γ-glutamyl valine. With the identification of these two peptides in vegetative parts of the plant, it is hoped to be able to learn more about the function of the γ-glutamyl peptides in plants. (SWC 12-aA7)

Several years ago, γ-glutamyl-S-methyl cysteine was isolated from kidney bean and was found to be present in relatively large amounts. At that time, other peptides were found to be present in lower concentrations. These have now been isolated in crystalline form and identified as γ-L-glutamyl-L-leucine and γ-L-glutamyl-L-methionine. (SWC 12-aA7)

Further work has been done on the metabolism of S-methyl-L-cysteine, a sulfur amino acid closely related to methionine and cysteine. Using radioactive compounds, the possibility that methyl cysteine is derived from cysteine and that it is a precursor of methionine has been investigated. Radioactive methyl cysteine (methyl labeled) was given to detached bean leaves and to bean fruit attached to plants. The radioactivity in various amino acids was determined. The results strongly indicated the methyl group of methyl cysteine is a precursor of the methyl group of methionine, and therefore that methyl cysteine is a precursor of methionine, a compound for which the pathway of formation in higher plants is unknown. Radioactive cystine was given to beans and tested as in the above methyl cysteine experiments. Although radioactivity was found in methyl cysteine, it was not high enough to indicate that cysteine is a good precursor of

methyl cysteine. From the radioactivity in other compounds, it appeared that alanine may be a precursor of cystine. Prior to this finding, serine has been assumed to be the only precursor of cystine. Cystine is thought to be the precursor of all the reduced sulfur compounds in plants. (SWC 12-aA7)

Previous work on the metabolism of nitrogen compounds by Chlorella indicated that arginine was metabolized to citrulline, rather than to ornithine as it is in most organisms. Enzymatic work with Chlorella has definitely shown the presence of arginine desimidase, which converts arginine to ammonia and citrulline. This indicates why arginine is a good nitrogen source for Chlorella and other algae. This is the first clear-cut evidence for this enzyme in green plants, although it has been found in some species of bacteria. (SWC 12-aA7)

D. Chemistry of Micronutrients in Soils

Continuing investigations into the reactions of heavy metals with soils have revealed certain hitherto unrecognized properties. Pre-treatment of clays with fluoride seriously reduces the ability of these clays to combine specifically with Co. Since the effect can be reversed with base, it appears to be due to replacement by F^- of surface OH^- groups involved in the Co^{++} reaction. Careful examination of the effect of Ca^{++} in the system disclosed that this ion does not compete with Co^{++} for the adsorption sites under study. The total lack of competition in this case indicates that the adsorption site is not negatively charged. A theoretical treatment was developed for the competition of ions for an adsorbing surface which, if certain assumptions can be made, can be used to show that hydrolysis of the ion is involved in the adsorption of Co by montmorillonite. (SWC 12-aA5)

The research program on the chemistry of micronutrients in soils is being extended to treat the question of specific rhizosphere effects. With a view toward evaluating the contribution of plant root exudates on the chemical behavior of heavy metals in soils, techniques have been or are being developed to collect quantities of root exudate and to separate from the other components those substances capable of complexing heavy metals. It has already been shown that this unconcentrated exudate will promote a higher solution concentration of Zn in contact with soil. Attempts in the coming year will be directed toward separating the individual active fractions, and making a preliminary survey of their properties. (SWC 12-aA5)

In response to a request from the A.O.A.C., an analytical method was developed for the determination of Co in fertilizers. The procedure modifies and combines techniques available in the literature to provide a relatively quick colorimetric assay sensitive to 5 ppm. Co in the fertilizer. (SWC 12-aA5)

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Soil and Plant Composition as Factors Affecting the Distribution of Nutritional Problems in Livestock

Allaway, W. H. 1962. Relation of soil to plant and animal nutrition. Proc. Cornell Nutr. Conf. for Feed Mfgrs.: 13-23.

Anderson, M. S., Lakin, H. W., Beeson, K. C., Smith, Floyd F., and Thacker, E. H. 1961. Selenium in agriculture. USDA Handbook No. 200: 1-65.

Beeson, K. C. 1960. Chemical fertilizer and crop quality. Plant Food Review, 6(2): 22.

Binns, Wayne, James, Lynn F., Shupe, James L., and Thacker, E. J. 1962. Cyclopian-type malformation in lambs. Archives of Environmental Health 5: 106-108.

Hodgson, J. F., Leach, R. M., Jr., and Allaway, W. H. 1962. Micronutrients in soils and plants in relation to animal nutrition. Agric. & Food Chem. 10(3): 171-174.

Trace Element Functions and Interactions in Animal Nutrition

Leach, R. M., Jr., Hodgson, J. F., and Allaway, W. H. 1962. Soil mineral deficiencies in livestock. Jour. Soil & Water Conservation 17(3): 114-117.

Leach, R. M., Jr., and Muenster, Anna-Marie. 1962. Studies on the role of manganese in bone formation. I. Effect upon the mucopolysaccharide content of chick bone. Jour. of Nutr. 78(1): 51-56.

Leach, R. M., Jr., Norris, L. C., and Scott, M. L. 1963. The effect of diethylstilbestrol on choline deficiency in the chick. Poultry Sci. 41: 1728-1732.

Biosynthesis of Amino Acids, Peptides and Proteins

Apgar, Jean, and Holley, Robert W. 1962. Differences between yeast and rat-liver amino acid-specific "soluble" ribonucleic acids shown by countercurrent distribution. Biochem. & Biophys. Res. Comm. 8(5): 391-393.

Arnold, Wilfred Neils, and Thompson, John F. 1962. The formation of (+) S-methyl-L-cysteine sulfoxide from S-methyl-L-cysteine in crucifers. Biochim. Biophys. Acta, 57: 604-606.

Baker, James E., and Thompson, John F. 1962. Metabolism of urea and ornithine cycle intermediates by nitrogen-starved cells of Chlorella vulgaris. Plant Physiol. 37(5): 618-624.

Brunngraber, Elinor F. 1962. A simplified procedure for the preparation of "soluble" RNA from rat liver. Biochem. & Biophys. Res. Comm., 8(1): 1-3.

Holley, Robert W. 1963. Large-scale preparation of "soluble" ribonucleic acid from yeast. Biochem. & Biophys. Res. Comm., 10(2): 186-188.

Morris, Clayton J., and Thompson, John F. 1962. The isolation and characterization of γ-L-glutamyl-L-tyrosine and γ-L-glutamyl-L-phenylalanine from soybeans. Biochem. 1(4): 706-709.

Morris, Clayton J., Thompson, John F., Asen, Sam, and Irreverre, Filadelfo. 1962. The isolation of γ-L-glutamyl-8-alanine from iris bulbs. Jour. Biol. Chem., 237(7): 2180-2181.

Thompson, John F., and Gering, Rose K. 1962. Preparation of N^{α}-acetylornithine. Arch. Biochem. & Biophys. 99(2): 326-327.

Thompson, John F., Arnold, Wilfred N., and Morris, Clayton J. 1963. A sensitive qualitative test for sulfoxides on paper chromatograms. Nature 197(4865): 380.

Thompson, John F., Morris, Clayton J., Arnold, Wilfred N., and Turner, Donella H. 1962. γ-Glutamyl peptides in plants. In Amino Acid Pools: 54-64. Edited by J. T. Holden, Elsevier Publishing Co., Amsterdam, Holland.

Weisblum, Bernard, Benzer, Seymour, and Holley, Robert W. 1962. A physical basis for degeneracy in the amino acid code. Natl. Acad. Sci., 48(8): 1449-1454.

Chemistry of Micronutrients in Soils

Hodgson, J. F., and Tiller, Kevin G. 1962. The location of bound cobalt on 2:1 layer silicates. Clays and Clay Minerals, 9, 404-411.

Tiller, Kevin G., and Hodgson, J. F. 1962. The specific sorption of cobalt and zinc by layer silicates. Clays and Clay Minerals, 9, 393-403.

AREA 13: FERTILIZER TECHNOLOGY INVESTIGATIONS RESOURCES, PRODUCTION, AND IMPROVEMENT

Problem. In a rapidly shifting agricultural economy, fertilizers must be fitted to the changing needs if the farmer is to realize maximal returns for each dollar invested in fertilizer and protect his profits against inevitable rising costs. Manufacturing procedures, insofar as they influence nutrient content, nutrient quality, and physical character of the fertilizer, must be aligned with use benefits in order to permit the design of products that are fully adapted to the service requirements of different crops under particular management practices.

USDA PROGRAM

The Division has a continuing long-term program involving inorganic and physical chemists, a soil scientist, a commodity analyst, and a chemical engineer engaged in basic chemical and physical studies and the application of known principles to the solution of fertilizer problems in the factory and in field distribution.

The Division scientific effort devoted to research in this area totals 24.5 professional man-years. Of this number, 14.0 are devoted to materials development and refinement; 3.5 to mixed-fertilizer investigations; 3.5 to standardization of specifications and test procedures for marketed fertilizers; 0 to agricultural chemical additives; and 3.5 to consumption trends and use patterns.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Materials Development and Refinement

Nutrient release from nitrogen carriers is gaged largely by the rate of biological nitrification--a process that can be followed under standardized conditions in relatively inexpensive laboratory experiments. During the year, two series of such experiments were run for the purpose of comparing the nitrification rates of selected nitrogen-bearing materials with provision for delineating the effect of granule size within the practical size range and the influence of the method (compaction) used to form the granules on the speed of nitrification. The test materials were ammonium sulfate, urea, and milorganite, which were considered as reference materials, and resin-coated urea, magnesium ammonium phosphate, oxamide, ureaform produced by several manufacturers, including a urea-crotonaldehyde (Floranid) and a selection of commercial ureaform containing mixed fertilizers.

The results of these tests show (1) that the compaction method for forming granules had no deleterious effect on the nitrification character of the fertilizer, (2) that the inhomogeniety inherent in resin-coated. fertilizer necessitates the use of much larger test portions than are customary in conventional nitrification tests, (3) that only oxamide and magnesium ammonium phosphate exhibited a definite retardation in nitrification with increase in granule size, and (4) that the ureaform type of fertilizers vary rather widely with respect to nitrification rate. The nitrification rates do not parallel as closely as heretofore expected the quality ratings found by the standard solubility test for this type of fertilizer. The latter observation poses a problem of special interest to both producer and consumer that requires further study to determine the cause for the indicated discrepancy between the results obtained by the two tests for quality of ureaform fertilizers. Such a study is underway.

Work on the analytical separation of water-soluble ammonic, nitric, and amidic forms of nitrogen with the use of ion-exchange columns was resumed in the summer of 1962. Previous findings as to effective operating conditions for the exchange columns were checked and confirmed with some refinements. Two glass columns in series contained, respectively, a cation-exchange resin in sodium form and an anion-exchange resin in chloride form. According to design, the separation is accomplished by catching the ammonic and nitric forms on the respective resins and letting the urea remain in the effluent. The forms on the resins are recovered singly by elutriation, whereupon the three forms are ready for estimation in separate solutions. Quantitative recovery of urea in the elutriate presents a problem that requires rather careful control of operating conditions. The results justify continued study looking to adaptation of the technique to general fertilizer use where likely-interfering substances will be encountered.

Work completed early in the year provides techniques for the laboratory measurement of critical characteristics of the network of void spaces (pores) in phosphate rock and for appropriate interpretation of the results that, supplemented by previously devised indices of quality, permits reliable conclusions as to the suitability of the rock for superphosphate manufacture by conventional methods or for direct application to soil. The method depends upon measurement of pore volumes in relation to pore size, namely; total volume of pores (1) with radii up to 40 angstroms* (very fine pores), determined by nitrogen desorption, (2) with radii up to 300 angstroms (fine pores), determined by nitrogen desorption, (3) with radii up to 20,000 angstroms, determined by nitrogen desorption and mercury porosimeter, and (4) with radii up to 60,000 angstroms, determined from densities measured by displacement of helium and mercury, respectively. The reactiveness of phosphate rock with respect to mineral acid or to the soil environment is governed by the volume of fine and very fine pores. Evaluation of an unknown specimen of rock is routinely

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* 1 angstrom = 0.004 millionth inch approximately.

accomplished by comparing these volumes with similar figures for rocks of known performance characteristics. Accordingly, rock from newly found deposits can be dependably rated with respect to rocks familiar to users without extensive and costly pilot-plant tests or large-scale agronomic comparisons.

The study of the effect of calcination temperature on the pore structure of Utah and Morocco rock was studied over the temperature range 450° to 1050° C. Calcination at 450° C. increased the pore volume of the Utah rock and decreased that of the Morocco rock. Above this temperature, the pore volume of both rocks decreased with an increase in calcination temperature--rather slowly up to about 700°, where it dropped abruptly to one-third or less, then fairly slowly to low values at 1050°. The decrease was most marked in the case of the fine pores, which govern rock reactiveness.

Noteworthy accomplishments on the chemical and physical composition of agriculture limestones include (1) the development of procedures for the simultaneous spectrochemical determination of aluminum and seven trace elements, (2) the use of these procedures and others in a survey of the composition of limestone produced in 35 states, (3) sieve analysis of a wide variety of stone, which show the levels of fineness in practice, (4) comparison of wet- and dry-sieving procedures on selected specimens of stone for the purpose of relating certain sieving problems to the physical character of the stone, and (5) a large collaborative study with five state experiment stations to evaluate methods for gaging the reactiveness of limestone. These studies have supplied factual information of listing value to producers, consumers, and consumer counselors. The results provide data needed as a basis for realistic trade specifications.

The experimental work with flue dust from cement kilns shows chlorine content which ranges up to 2 percent. Other elements present in amounts sufficient to impart undetermined plus values to the dust are potassium, usually 2 to 8 percent of K_2O, of which 30 to 90 percent is water soluble, and sulfur, usually 2 to 10 percent. The neutralizing capacity of the dust runs about 85 percent that of limestone. The dust was found to be about as effective for the correction of soil acidity as pulverized limestone (60 to 75 percent passing U. S. Sieve No. 100) and superior to coarser grades.

Another byproduct given experimental attention during the year is low-carbon ferrochromium slag, of which some 200 tons daily are produced in the United States. This material is proposed for use as a liming material, and a question has been raised as to possible deleterious effects of its chromium content (up to 1 percent of Cr) on crops. A greenhouse experiment, now almost completed, is expected to indicate the liming quality of the slag and to provide a check on the possibility of undesirable chromium uptake by alfalfa and corn. The chromium uptakes in

slag-treated pots does not appear to be significantly different from that in limestone-treated pots.

A greenhouse experiment was conducted to evaluate zinc carriers for fertilizer use with alfalfa on Lakeland and Sagemoor soils. The test materials, applied in amounts equivalent to 3 parts of zinc per million parts of soil, were zinc sulfate as a comparison standard, three glasses of different composition in four finenesses, zinc ammonium phosphate in two finenesses, three natural minerals (hemimorphite, willemite and sphalerite) and a zinc chelate (EDTA). Crop utilization of zinc in individual glasses was found to vary in orderly fashion with fineness. The effect of change in glass composition on zinc uptake was less than expected. In contrast to earlier findings with boron-containing glass, zinc utilization did not parallel at all closely the soluble zinc found by laboratory tests. In the first harvest, the chelate supplied about twice as much nutrient to the crop as did the sulfate; in later harvests, the difference gradually declined. The posture of the results indicate that the reactivity of hemimorphite lies close to the optimum for long term steady zinc supply to alfalfa. Delineation of these findings in further study is anticipated.

Suitable standard materials for the calibration of scales of phosphate solubility and availability are needed as comparison standards in fertilizer evaluation studies. Such materials must be reproducible in coarsely crystalline form and obtainable in appropriate quantities for experimentation. To this end, a promising procedure for the synthesis in pound lots of strengite, a very sparingly soluble iron phosphate, was devised. Also, attention was given to the synthesis of calcium phosphoramidata, $CaPO_3NH_2$, which may show a solubility within the broad solubility gap between dicalcium phosphate and the ammonium phosphates.

B. Mixed-Fertilizer Investigations

Preparation of test fertilizers and other materials for experimentation by persons outside the U. S. Fertilizer Laboratory was continued in response to demand. During the calendar year 1962, about 4 curies of phosphorus-32 was received and processed into 26 kinds of fertilizers that contained in all 47 pounds of phosphoric oxide. These materials were consigned in 53 shipments to 10 cooperators in the United States, 5 in Canada and 13 in Europe, Asia, and South America for use in a variety of studies, including evaluation of water-soluble phosphate, phosphorus uptake, placement and rate of fertilization, phosphate migration in soil, and uniform experiment on rice fertilization (7 countries). Also 9 shipments of nonradioactive superphosphate were prepared for use in the forementioned experiments.

Several lots of special fertilizers (nonradioactive) prepared for experimental use included: 8 lots of 5-10-10 fertilizer with and without added magnesium for the Department of Agronomy, University of Maryland;

about 200 pounds of homogeneous 10-20-20 for fertilizer distribution experiment at Florence, South Carolina; 5 lots of material for nutrient-balance field experiments in Georgia, Alabama, and Wisconsin; 4 small lots of basic calcium phosphate substantially free of water-rich surface compounds for theoretical study in Bone Char Research Project, National Bureau of Standards, two 100-pound lots of molybdenum-containing triple superphosphate for use at 6 state experiment stations in the South, and 2 small lots of selenium-containing superphosphate for the U. S. Plant, Soil and Nutrition Laboratory.

The study on the influence of particle size of input materials on the behavior of fertilizer mixtures in granulation processes was continued with attention to the potassium-bearing ingredient. The investigation is concerned with combinations of particle size distribution in which three size distributions of potassium chloride--coarse, medium, and fine, each in normal, standard (uniform over range) and two skewed patterns, are combined singly with a standard size distribution of superphosphate and ammonium sulfate to yield a 5-20-20 mixture. Granulation efficiency was evaluated in terms of measurable properties of the granulate--sensitivity of granule formation to variations in the moisture content, extent of granule growth, and uniformity of nutrient distribution among size fractions of the granulated fertilizer. Coarse potassium chloride showed the best performance. When its particle size distribution was skewed to the coarse side, performance was least sensitive to moisture variations such as occur in factory operation, as shown by consistently high yields of on-size product. On the other hand, nutrient distribution in the granulate was notably better with the size distribution skewed to the fine side where the yield of on-size product was somewhat lower and less consistent.

Laboratory tests conducted on a 0-15-30 fertilizer show that water glass solution is an effective granulation aid. The addition of water glass (40 pounds per ton) lowered the water requirement for granulation with resultant reduction in the necessary drying time and markedly improved the yield of on-size product and increased the hardness of the granule.

Slurry processes for granulating fertilizers by spraying onto small nuclei successive coatings of a slurry suspension of the ingredients appear to be gaining favor in industry. A laboratory unit for carrying out this process on 6- to 8-pound lots was designed and built in the Division Instrument Design Shop. It is being used to study the influence of different potassium compounds on the granulative character of fertilizer mixtures. The results show that the use of nitrate of potassium favors high yields of on-size product with a moisture requirement somewhat greater than for the sulfate but less than for the chloride.

C. Standardization of Specifications and Test Procedures for Marketed Fertilizers

Work concerned with the development of improved methods of sampling and analysis of fertilizers, liming materials, and other soil amendments and with the promotion of uniformity of trade specifications was continued in cooperation with the Association of Official Agricultural Chemists, Association of American Fertilizer Control Officials, American Society for Testing and Materials, and other private associations, as well as with federal and state government agencies.

The quinolinium-molybdate procedure for determining phosphorus in fertilizers was made official first action on the basis of the results of a collaborative study reported last year, and the official volumetric method for water-soluble phosphorus in use for several years was modified by the addition of a hydrolysis step, which is necessary in the case of some currently marketed fertilizers that carry notable amounts of metaphosphates and/or pyrophosphates. An improved quinolinium-molybdate reagent was investigated and readied for collaborative study. The use of a commercially available automatic analyzer in fertilizer analysis for phosphorus has been under study for several months. Its use for nitrogen determination is being studied in the laboratory of Canada Packers Limited, and for potassium analysis in the University of Missouri. In the phosphorus study thus far, attention has been focused upon instrumental and operational modifications that make for accuracy and precision of results. Work under way looks toward its adaptation for use in an official procedure for phosphorus. The possibilities of the modified instrument as a means for lightening the load on analytical laboratories are now viewed with considerable enthusiasm in industrial and state fertilizer control laboratories.

Work looking to improvement of the official methods for determining water in fertilizers was continued with attention to ruggedness tests on official procedures. The findings provided a basis for actions to delete one of the official procedures and to modify another to the enhancement of its potential accuracy. A collaborative study of procedures is in progress. Investigation of the Karl Fischer reagent as a titrant for water in phosphate fertilizer was continued with a search for means to sharpen the endpoint in the presence of superphosphate.

The collaborative study of methods for determining silicon in agricultural liming materials was completed, and the findings served as a basis for the adoption of two of the procedures as official methods in October 1962, which concluded envisioned work on methods for silicon. Attention is now directed to a choice of methods for official use in determining aluminum, iron, titanium, manganese, and phosphorus in liming materials.

D. Agricultural Chemical Additives

Subject did not receive experimental attention in 1962.

E. Consumption Trends and Use Patterns

The regular annual survey of consumption of commercial fertilizers in the United States and Territories was completed for the year ended June 30, 1961. Fertilizers consumed during this period amounted to 25,567,130 tons (a 3.7 percent increase over 1960), comprising 15,734,711 tons of mixtures and 9,832,419 tons of materials, inclusive of secondary and micronutrient materials. Consumption of nitrogen amounted to 3,030,788 tons, 10.7 percent above the 1960 figure; available phosphoric oxide, 2,645,085 tons, 2.8 percent above the 1960 figure; and potassium oxide, 2,168,533 tons, 0.7 percent above the 1960 figure. The average nutrient content of mixtures was: N, 6.81; available P_2O_5, 13.15; and K_2O, 11.97. The averages for the preceding year were 6.50, 12.99, and 12.06, respectively.

The tonnages of fertilizers shipped to retail trade in bulk were compiled for 1960 and 1961 for comparison with published figures for earlier years. Bulk shipments continued to increase. In the years 1959 and 1961, the bulk-shipment shares in total shipments of fertilizer materials and mixtures, respectively, were: materials, 34.4 and 48.1 percent; and mixtures, 10.8 and 12.0 percent. The East North Central region (Ohio, Indiana, Illinois, Michigan, and Wisconsin) showed the largest proportion of bulk shipments--nearly 78 percent of the materials and above 16 percent of the mixtures.

The annual preliminary estimate of consumption of commercial fertilizers was made for the year ended June 30, 1962. The figures show that the tonnage of fertilizers, including secondary and micronutrient materials, was up about 4 percent in comparison with the preceding year. The indicated increases in nutrient consumption were as follows: N, 11.5; available P_2O_5, 4.4; and K_2O, 4.2 percent, respectively.

The development of information on the amounts of nitrogen, phosphorus, and potassium used on economic crops from the 1959 Census of Agriculture, delayed somewhat by tardiness of a few state reports, was substantially completed. From 1954 to 1959, the tonnage of commercial fertilizer consumed on farms, as distinguished from the total consumption found in the annual fertilizer consumption survey, increased 43 percent, whereas the increases in nutrient consumption were 46 percent for nitrogen, 12 percent for available phosphoric oxide, and 16 percent for potassium oxide. These advances reflect a general increase in fertilized acreage and in per-acre application of all three nutrients.

Collection of information on international developments concerned with fertilizers was continued by systematic review of sundry reports of the U. S. Foreign Service and the Food and Agriculture Organization of the United Nations, by perusal of trade journals, and by incidental contacts with informed sources. Information on fertilizers was supplied to the Agency for International Development, the Organization for European Cooperation, 31 foreign visitors, and 9 domestic companies interested in business expansion abroad.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Materials Development and Refinement

Chichilo, P., and Whittaker, Colin W. 1962. The mechanical and chemical analysis of agricultural limestone as affected by type of sieving. Assoc. Off. Agr. Chem. J., 45: 1004-1010.

Holden, E. R., and Bontoyan, W. R. 1962. Reactivity of boron glasses in aqueous solutions. Assoc. Off. Agr. Chem. J., 45: 455-463.

Holden, E. R., Page, N. R., and Wear, J. I. 1962. Properties and use of micronutrient glasses in crop production. J. Agr. Food Chem. 10: 188-192.

Mixed-Fertilizer Investigations

Hardesty, John O. (Chairman) 1962. Introduction to Micronutrient Symposium in Division of Fertilizer and Soil Chemistry, ACS Meeting, Chicago, Illinois, Sept. 3-8, 1961. J. Agr. and Food Chem., 10: 170 pp.

Hardesty, J. O. 1962. What's new in fertilizer conditioners? Farm Chem. 125 (8): 18, 20.

Hoffman, W. M., Ferretti, R. J., and Clark, K. G. 1962. Nutrients in the marketed fertilizers, calcium, magnesium, and sulfur contents of mixed fertilizers marketed in 1949-50 and in 1955-56. J. Agr. Food Chem., 10: 327-334.

Jackson, W. A., Heinly, N. A., and Caro, J. H. 1962. Trace elements in fertilizers. Solubility status of zinc carriers intermixed with N-P-K fertilizers. J. Agr. Food Chem., 10: 361-364.

Olive, B. M., and Hardesty, J. O. 1962. The effect of particle size on the granulation of triple superphosphate. J. Agr. Food Chem. 10: 334-337.

Standardization of Specifications and Test Procedures for Marketed Fertilizers

Hoffman, W. M. 1962. Determination of total phosphorus by the quinoline molybdate method. A collaborative study. Assoc. Off. Agr. Chem. J., 45: 999-1003.

Consumption Trends and Use Patterns

Scholl, Walter, Schmidt, G. W., and Wilker, C. A. 1962. Preliminary Report, Consumption of commercial fertilizers and primary plant nutrients in the United States year ended June 30, 1961. Farm Chem., 125(4): 60-61; Com. Fert. 104(4): 23-26, 65; Agri. Chem., 17(4): 34-36, 103-104; Croplife 9(3): 8, 56; Agr. Ammonia News, 12(3): 32-33.

Scholl, Walter, Schmidt, Gordon W., and Wilker, Caroline A. 1963. Consumption of commercial fertilizers and primary plant nutrients in the United States year ended June 30, 1961. ARS 41-19-5; Com. Fert. 106(3): 23-37.

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-Subheading
SWC 1	Sedimentation processes in relation to watershed development and protection.			
SWC 1-a1	Development and evaluation of means and measures for channel stabilization in the Northeast.	Beltsville, Md. East Aurora, N. Y.	Yes	1-A, D
SWC 1-b1	Sediment production, yield and delivery ratio in relation to climatic factors and watershed characteristics in the Southern Branch and at the U.S. Sedimentation Laboratory.	Oxford, Miss. Cartersville, Ga.	Yes	1-A
SWC 1-b2	Investigations of the nature and processes of reservoir sedimentation in the Southern Branch and at the U.S. Sedimentation Laboratory.	Oxford, Miss.	Yes	1-B
SWC 1-b3	Mechanics of sediment entrainment, transportation and deposition in natural and artificial channels in the Southern Branch and at the U.S. Sedimentation Laboratory.	Oxford, Miss. Watkinsville, Ga. Ft. Lauderdale, Fla.	Yes No	1-C
SWC 1-b4	Investigations of stream channel morphology in the Southern Branch and at the U.S. Sedimentation Laboratory.	Oxford, Miss. Watkinsville, Ga. Ft. Lauderdale, Fla.	Yes	1-D
SWC 1-b5	Development of structural measures for sediment control and for stream channel stabilization in the Southern Branch and at the U.S. Sedimentation Laboratory.	Oxford, Miss.	Yes	1-D
SWC 1-c1	Sediment sources, yields and deposition in agricultural watersheds in Corn Belt states.	Coshocton, Ohio	No	
SWC 1-c2	Stream channel stabilization, sediment control works in channels and mechanics of sediment entrainment, transportation and deposition therein, for Corn Belt states.	Madison, Wisc. Columbia, Mo. Coshocton, Ohio	Yes	1-D
SWC 1-d1	Rates and processes of reservoir sedimentation and deposition of sediment in channels and valleys of the Northern Plains.	Lincoln, Neb. Newell, S. Dak.	Yes	1-B
SWC 1-d2	Sediment production, yield, and delivery ratio in relation to climatic, geologic, and watershed characteristics of the Northern Plains.	Lincoln, Nebr. Hastings, Nebr. Newell, S. Dak.	Yes	1-A
SWC 1-e1	Sediment production, movement, and deposition in agricultural watersheds in the Southern Great Plains.	Riesel, Tex. Chickasha, Okla. Stillwater, Okla.	Yes	1-A
SWC 1-e2	Stream channel stabilization and sediment control works in channels in the Southern Great Plains.	Chickasha, Okla. Stillwater, Okla.	No	
SWC 1-f1	Sediment movement and deposition on upstream agricultural watersheds of the Pacific Northwest.	Boise, Idaho	No	
SWC 1-g1	Sediment yields of agricultural watersheds in the Southwest.	Tucson, Ariz. Santa Rosa, N. Mex. Riverside, Calif. Lompoc, Calif.	Yes	1-A
SWC 1-g2	Stream channel morphology and channel stability on agricultural watersheds in the Southwest.	Tucson, Ariz. Santa Rosa, N. Mex. Riverside, Calif.	No	
SWC 1-g3	Nature and processes of reservoir sedimentation in the Southwest.	Tucson, Ariz. Santa Rosa, N. Mex. Riverside, Calif.	Yes	1-B

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 2	Hydrology of agricultural watersheds and associated aquifers in relation to treatment for flood prevention and multiple use of water resources.			
SWC 2-a1	The relation of rain, snow, and frozen soils to the hydrology of agricultural watersheds in the Northeast.	Beltsville, Md. Danville, Vt. Blacksburg, Va. Morgantown, W. Va.	Yes	2-A
SWC 2-a2	Water yield in relation to climatic and watershed characteristics of land resource areas in the Northeast.	Beltsville, Md. Danville, Vt. Blacksburg, Va. Morgantown, W. Va.	Yes	2-C, E
SWC 2-a3	Storm runoff and flood flows in relation to climatic and watershed characteristics of land resource areas in the Northeast.	Beltsville, Md. Danville, Vt. Blacksburg, Va. Morgantown, W. Va.	Yes	2-F
SWC 2-aD1	Analytical hydrography in watershed engineering.	Beltsville, Md.	Yes	2-F
SWC 2-b1	Relation of climatic and watershed factors to runoff rates and volume yields in the Southern Branch.	Oxford, Miss. Ft. Lauderdale, Fla.	Yes	2-B
SWC 2-b2	Precipitation characteristics influencing runoff from agricultural watersheds in the Southern Branch.	Oxford, Miss. Ft. Lauderdale, Fla.	No	
SWC 2-b3	Runoff production by unit source area agricultural watersheds in the South.	Oxford, Miss.	Yes	2-E
SWC 2-b4	Subsurface and ground water accretion, depletion, movement and contribution to streamflow for agricultural watersheds in the Southern Branch.	Oxford, Miss.	Yes	2-C, D
SWC 2-c1	Precipitation and snow melt characteristics influencing runoff from agricultural watersheds in Corn Belt states.	Coshocton, Ohio Madison, Wisc.	Yes	2-A
SWC 2-c2	Runoff production by unit source area agricultural watersheds in Corn Belt states.	Coshocton, Ohio Madison, Wisc.	No	
SWC 2-c3	Relation of climatic and watershed factors to storm runoff in Corn Belt states.	Coshocton, Ohio Madison, Wisc.	No	
SWC 2-c4	Relation of climatic and watershed physiographic and cultural factors to water yield in Corn Belt states.	Columbia, Mo. Coshocton, Ohio Madison, Wisc.	Yes	2-E
SWC 2-c5	Aquifer and subsurface relationships in the hydrology of upstream agricultural watersheds in Corn Belt states.	Coshocton, Ohio Madison, Wisc.	Yes	2-B, C, D
SWC 2-d1	Water yield as related to integrated climatic and watershed characteristics in the Northern Plains.	Lincoln, Nebr. Hastings, Nebr. Newell, S. Dak.	Yes	2-E
SWC 2-d2	Storm runoff and floods as related to integrated climatic and watershed characteristics in the Northern Plains.	Hastings, Nebr. Newell, S. Dak.	Yes	2-A
SWC 2-e1	Precipitation characteristics influencing runoff from agricultural watersheds in the Southern Plains.	Chickasha, Okla. Riesel, Tex. Bushland, Tex.	Yes	2-A
SWC 2-e2	Runoff production by unit source areas in the Southern Plains.	Chickasha, Okla. Stillwater, Okla. Riesel, Tex.	Yes	2-B, E
SWC 2-e3	Relation of climatic and watershed factors to storm runoff in the Southern Plains.	Chickasha, Okla. Stillwater, Okla. Riesel, Tex.	Yes	2-F
SWC 2-e4	Relation of climatic and watershed physiographic and cultural factors to water yield in the Southern Plains.	Chickasha, Okla. Stillwater, Okla. Riesel, Tex.	Yes	2-C, E

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963 (Continued)

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 2-f1	Aquifer-streamflow interrelationships in upstream agricultural watersheds of the Pacific Northwest.	Boise, Idaho	Yes	2-A, C, D
SWC 2-f2	Precipitation characteristics influencing hydrologic performance of agricultural watersheds in the Pacific Northwest.	Boise, Idaho Moscow, Idaho	No	
SWC 2-f3	Runoff and sediment movement on unit source watersheds of the Pacific Northwest as influenced by climate, soils, vegetation, and topography.	Boise, Idaho Moscow, Idaho	No	
SWC 2-f4	Water accumulation, flood-wave movement and water yield from complex watersheds of the Pacific Northwest.	Boise, Idaho	No	
SWC 2-g1	Precipitation characteristics influencing the hydrology of agricultural watersheds in the Southwest.	Tucson, Ariz. Lompoc, Calif. Santa Rosa, N. Mex.	Yes	2-A
SWC 2-g2	Relation of integrated climatic, watershed, and cultural factors to storm runoff from agricultural watersheds in the Southwest.	Tucson, Ariz. Santa Rosa, N. Mex.	No	
SWC 2-g3	Relation of integrated climatic, watershed, and cultural factors to water yields from agricultural watersheds in the Southwest.	Tucson, Ariz. Lompoc, Calif. Santa Rosa, N. Mex.	Yes	2-B, C, D

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-Subheading
SWC 3	Hydraulics of irrigation, drainage and watershed protection and water supply structures, channels, and facilities.			
SWC 3-c1	Hydraulic design of structures for water use and control in the Corn Belt.	Minneapolis, Minn.	Yes	3-A, B
SWC 3-e1	The hydraulics and measurement of channel, flood plain, and overland flow in the Southern Plains.	Stillwater, Okla.	Yes	3-A, C, D
SWC 3-e2	Hydraulic design of structures for water use and control in the Southern Plains.	Stillwater, Okla.	Yes	3-B
SWC 3-g1	The hydraulics of channel, flood plain, and overland flows in the Southwest.	Tucson, Ariz.	Yes	3-A

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 4	Conservation of water supplies for agricultural use.			
SWC 4-b1	Development of water supplies for irrigation in the South.	Tifton, Ga.	Yes	4-B-1
SWC 4-c1	Improvement of water supply sources and storage facitlities in the Corn Belt.	Columbia, Mo.	Yes	4-A-1
SWC 4-d1	Facilities, methods and design criteria for pumping, conveying, controlling and measuring irrigation water in the Northern Plains.	Fort Collins, Colo.	Yes	4-B-2
SWC 4-e1	Conservation and management of playa lake water for recharge and irrigation in the Southern Plains.	Bushland, Tex.	Yes	4-C
SWC 4-g1	Control of water use by nonbeneficial plants and evaporation losses from storage and conveyance structures in the Southwest.	Reno, Nev. Logan, Utah	Yes	4-A-2,B-1,D
SWC 4-g2	Recharge facilities, methods, principles and design criteria for storing water in underground reservoirs in the Southwest.	Fresno, Calif.	Yes	4-C
SWC 4-g3	Control of agricultural water supply and conveyance seepage losses in the Southwest.	Logan, Utah Reno, Nev.	Yes	4-A-1,B-1
SWC 4-gG1	Measurement, evaluation and control of seepage losses.	Tempe, Ariz.	Yes	4-A-1
SWC 4-gG2	Atmospheric and related boundary mechanisms in water vapor losses from plant, soil and water surfaces.	Tempe, Ariz.	Yes	4-A-2
SWC 4-gG3	Measurement, evaluation and control of infiltration to conserve water.	Tempe, Ariz.	Yes	4-B-1,C
SWC 4-gG4	Physical processes in the soil affecting preventable losses of water by surface evaporation.	Tempe, Ariz.	Yes	4-A-2
SWC 4-gG5	Water measurement and control for water conservation.	Tempe, Ariz.	Yes	4-B-2
A10-SWC-25 (Israel)	Removal of suspended matter and turbidity from water by flocculation with polyelectrolyte coagulants and coagulation aids.	Technion, Israel	No	

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 5	Irrigation principles, requirements, practices, and facilities for efficient use of water on farms.			
SWC 5-a1	Irrigation practices and factors affecting the water requirement of crops in different land resource areas of the Northeast.	New Brunswick, N. J. Orono, Maine Blacksburg, Va.	Yes	5-A-2
SWC 5-b1	Irrigation requirements, practices and methods of application for efficient production of crops in the Southeast.	Thorsby, Ala. Watkinsville, Ga. Tifton, Ga. State College, Miss. Ft. Lauderdale, Fla.	Yes	5-A-1, 2, 3
SWC 5-c1	Improvement in performance and design of irrigation systems in the Corn Belt.	Columbia, Mo.	Yes	5-B
SWC 5-d1	Irrigation practices, requirements and design criteria for efficient use of water and sustained crop production in the Northern Plains.	Grand Junction, Colo. Fort Collins, Colo. Lincoln, Nebr. Mitchell, Nebr. Laramie, Wyo. Newell, S. Dak.	Yes	5-A-1, B, D
SWC 5-e1	Irrigation water management for maximum use efficiency in growing crops in the Southern Plains.	Weslaco, Tex. Bushland, Tex.	No	
SWC 5-f1	Irrigation requirements, principles, and practices for efficient use of water in the Pacific Northwest.	Prosser, Wash.	Yes	5-A-2, 3
SWC 5-f2	Surface and sprinkler design and operation principles and facilities for efficient water use in the Pacific Northwest.	Ontario, Ore. Boise, Idaho	Yes	5-C, D
SWC 5-g1	Basic irrigation principles in the Southwest.	Brawley, Calif. Logan, Utah Reno, Nev.	Yes	5-B
SWC 5-g2	Irrigation requirements of forage and cultivated crops in the Southwest.	Reno, Nev. Pomona, Calif. Lompoc, Calif. Brawley, Calif.	Yes	5-A-1, 2
SWC 5-g3	Intake, transmission and storage of water in irrigated lands in the Southwest.	Logan, Utah Reno, Nev. Brawley, Calif. Pomona, Calif.	Yes	5-A-3
A10-SWC-11	Further studies on the Blaney and Criddle formula U-KF to ascertain consumptive use of water by plants by means of analysis of climatological data.	Rehovoth, Israel	No	

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 6	Drainage principles, requirements, practices, and facilities for protection of crops and soils.			
SWC 6-a1	Development and evaluation of surface and subsurface drainage practices in different land resource areas of the Northeast.	Ithaca, N. Y. Burlington, Vt. Blacksburg, Va.	Yes	6-A, C
SWC 6-b1	Drainage requirements of crops in the South.	Ft. Lauderdale, Fla. Raleigh, N. C.	Yes	6-E-1
SWC 6-b2	Design, installation and maintenance of surface and subsurface drainage systems with or without land forming and conditioning in the South.	Fleming, Ga. Ft. Lauderdale, Fla. Baton Rouge, La.	Yes	6-A, E-2
SWC 6-c1	Improvement and modernization of surface and subsurface drainage practices and facilities in the Corn Belt.	Minneapolis, Minn. Morris, Minn. Columbus, Ohio Madison, Wisc.	Yes	6-B, C, E-3
SWC 6-d1	Drainage facilities, methods, and design criteria for protection and improvement of agricultural crops and soils in the Northern Plains.	Fort Collins, Colo. Grand Junction, Colo. Grand Forks, N. Dak.	Yes	6-B, D
SWC 6-e1	Basic drainage principles in the Southern Plains.	Weslaco, Tex.	Yes	6-E-2
SWC 6-e2	Surface and subsurface drainage systems, methods, materials, and evaluation in the Southern Plains.	Chickasha, Okla. Weslaco, Tex.	Yes	6-B, D
SWC 6-g1	Basic drainage principles in the Southwest.	Logan, Utah Pomona, Calif.	Yes	6-D, E-2
SWC 6-g2	Drainage facilities, methods and evaluation for irrigated lands in the Southwest.	Pomona, Calif. Brawley, Calif. Reno, Nev. Logan, Utah	Yes	6-B, D
SWC 6-g3	Drainage and aeration requirements of crops on irrigated lands in the Southwest.	Reno, Nev.	No	
SWC 6-gF1	Principles of drainage as related to salt-affected soils in the Southwest.	Riverside, Calif.	Yes	6-D

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 7	Saline, sodic, and related soils problems, and quality of irrigation waters and their relation to plant growth processes.			
SWC 7-a1	Investigations of the effects of using saline and industrial waste waters on the yield and quality of plants, and on physical and chemical characteristics of soils.	New Brunswick, N.J. Norfolk, Va.	Yes	7-A, B, E
SWC 7-b1	The effect of brackish water on plants and soils in the South.	Fleming, Ga.	Yes	7-B
SWC 7-d1	Improvement and management of saline and sodic soils of the Northern Plains.	Huntley, Mont. Mandan, N. Dak. Grand Junction, Colo.	Yes	7-D, E
SWC 7-e1	Saline and sodic soils and irrigation water quality problems in the Rio Grande River basin.	Weslaco, Tex.	Yes	7-A, D
SWC 7-f1	Soil and water management practices for the control or alleviation of saline and sodic soil problems in the Pacific Northwest.	Ontario, Ore.	Yes	7-D
SWC 7-g1	Effect of leaching, amendments, water quality and soil and crop management practices on the soluble salt and adsorbed cation status of salt-affected southwestern soils.	Pomona, Calif.	No	
SWC 7-gF1	Mechanisms of reactions between dissolved and adsorbed constituents of salt-affected soils.	Riverside, Calif.	Yes	7-A
SWC 7-gF2	Structure, organic matter, and microbial relations in salt-affected soils.	Riverside, Calif.	Yes	7-A
SWC 7-gF3	Methods for the diagnosis and study of salinity in soils and water.	Riverside, Calif.	Yes	7-A
SWC 7-gF4	Soil physical and chemical conditions in relation to plant growth on salt-affected soils.	Riverside, Calif.	Yes	7-B
SWC 7-gF5	Tolerance of economic plants to salinity and exchangeable sodium.	Riverside, Calif.	Yes	7-B
SWC 7-gF6	Plant-water relationships under saline, drougth, or high exchangeable-sodium conditions.	Riverside, Calif.	Yes	7-B
SWC 7-gF7	Effects of salinity and exchangeable-cation status on absorption, distribution, and metabolic effectiveness of ions in plants.	Riverside, Calif.	Yes	7-B
SWC 7-gF8	Effects on plants of specific ions associated with salinity or exchangeable sodium.	Riverside, Calif.	Yes	7-B
SWC 7-gF9	Influence of climatic and edaphic factors on plant response to salinity and exchangeable sodium.	Riverside, Calif.	No	
SWC 7-gF10	Chemical composition of irrigation waters in relation to their suitability for use.	Riverside, Calif.	Yes	7-C
SWC 7-gF11	Principles of salinity control, including the amelioration of salt-affected soils by leaching and the use of amendments.	Riverside, Calif.	Yes	7-E
SWC AID-0-1-2	The salt tolerance of plants of special importance to AID missions.	Riverside, Calif.	Yes	7-B
SWC AID-0-1-4	Interpretation and adaptation for AID use of techniques for diagnosis and improvement of salt-affected soils.	Riverside, Calif.	Yes	7-A

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 8	Water and wind erosion control principles, practices, systems, and prediction methods for conservation of crop and rangelands.			
SWC 8-a1	Determination and evaluation of factors affecting water runoff and erosion in the different land resource areas of the Northeast as related to soil and water conservation practices.	Orono, Maine Durham, N. H. Blacksburg, Va. Ithaca, N. Y.	Yes	8-A-1, 2, B-1, D-1
SWC 8-b1	Effects of soil, topography, climate, cropping and management procedures on runoff and erosion, and on the prediction of soil losses in the South.	Watkinsville, Ga. Tifton, Ga. Holly Springs, Miss.	Yes	8-B-1
SWC 8-b2	Development of supporting practices, systems, techniques and devices for runoff and erosion control in the South.	Watkinsville, Ga. Oxford, Miss.	Yes	8-D-1
SWC 8-c1	Basic principles and mechanics of rainfall, runoff, soil movement and loss.	Lafayette, Ind. Morris, Minn. Urbana, Ill. Ames, Iowa Brookings, S. Dak.	Yes	8-A-1, 2
SWC 8-c2	Evaluation of climatic, topographic, soil and crop management factors in relation to water management and erosion control.	Lafayette, Ind. Columbia, Mo. LaCrosse, Wisc. Morris, Minn. Ames, Iowa Brookings, S. Dak.	Yes	8-B-1, D-1
SWC 8-c3	Development and refinement of methods for predicting field runoff and soil loss.	Lafayette, Ind.	Yes	8-C-1
SWC 8-c4	Development of supporting runoff and erosion control practices and systems.	LaCrosse, Wisc. Columbia, Mo. Morris, Minn. Ames, Iowa	No	
SWC 8-d1	Water erosion and its control on irrigated and nonirrigated lands in the Northern Plains.	Lincoln, Nebr.	Yes	8-A-2, B-1
SWC 8-e1	Wind erosion control in the Southern Plains.	Manhattan, Kans. Bushland, Tex. Big Spring, Tex.	Yes	8-B-2, C-2, D-3
SWC 8-e2	Interrelations among soil-cover-practice complexes, precipitation, runoff, and erosion losses in the Southern Plains.	Temple, Tex. Cherokee, Okla. Chickasha, Okla. Bushland, Tex. Manhattan, Kans.	Yes	8-C-3
SWC 8-e3	Runoff water management for erosion control, moisture conservation, and leaching of saline soil areas.	Cherokee, Okla. Weslaco, Tex. Bushland, Tex. Big Spring, Tex. Hays, Kans. Chickasha, Okla.	Yes	8-D-2
SWC 8-f1	Erosion and runoff control practices and systems to conserve soil and water resources in the Pacific Northwest.	St. Anthony, Ida. Pendleton, Ore. Pullman, Wash.	Yes	8-B-1, 2
SWC 8-f2	Fundamental aspects of soil erosion in the Pacific Northwest.	Pullman, Wash.	No	

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 9	Moisture conservation for the efficient and effective use of precipitation on crop and range lands.	Beltsville, Md.		
SWC 9-c1	Development of soil management systems for efficient use of soil moisture in the Corn Belt region.	Morris, Minn. Columbia, Mo.	Yes	9-A-1, A-7, C-1
SWC 9-d1	Improved water conservation and use on nonirrigated lands of the Northern Plains.	Akron, Colo. Ft. Collins, Colo. Bozeman, Mont. Sidney, Mont. Alliance, Nebr. Lincoln, Nebr. North Platte, Nebr. Mitchell, Nebr. Mandan, N. Dak. Newell, S. Dak. Archer Substation, Wyo. Laramie, Wyo.	Yes	9-A-2, A-3, A-4, A-5, A-6, B-1, B-2, C-2, C-6
SWC 9-e1	Conservation and efficient use of precipitation in the Southern Great Plains.	Big Spring, Tex. Bushland, Tex. Weslaco, Tex. Manhattan, Kans. Woodward, Okla.	Yes	9-A-2, B-4, B-5, C-2, C-3, C-4, C-5
SWC 9-f1	Moisture conservation principles and practices in the Pacific Northwest.	Pendleton, Ore. St. Anthony, Ida. Moro, Ore.	Yes	9-A-1, A-3
SWC 9-g1	Perfecting cropping sequences, land and water management systems, and cultural practices to conserve and efficiently utilize precipitation.	Riverside, Calif.	Yes	9-B-3

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-Subheading
SWC 10	Soil properties, processes, and management in relation to the conservation and efficient use of land and water resources.	Beltsville, Md.		
SWC 10-a1	Development of improved soil management and conservation practices on croplands in different land resource areas of the Northeast.	Presque Isle, Maine Orono, Maine Marlboro, N. J. Marcellus, N. Y. Blacksburg, Va.	Yes	10-A-7, C-1, C-2, C-4
SWC 10-a2	Development of improved soil management practices for grassland soils in different land resource areas of the Northeast.	St. College, Pa.	Yes	10-A-5, C-5
SWC 10-36 (a3) (supercedes 10-aB5)*	Fixation of atmospheric nitrogen by rhizobia.	Beltsville, Md.	No	
SWC 10-aB1	Fixation of ammonium ion in soils and its release to plants.	Beltsville, Md.	Yes	10-A-2
SWC 10-aB2	Biological transformations of nitrogen in soil, including biological interchange in the rhizosphere, nonsymbiotic fixation, gaseous losses, and accumulation of toxic products.	Beltsville, Md.	Yes	10-A-1, A-2
SWC 10-aB3	Humus formation in soils and the interaction of organic compounds with clays.	Beltsville, Md.	Yes	10-D-1, D-2
SWC 10-aB4	Evaluation of soil-pesticide complexes, including their decomposition.	Beltsville, Md.	Yes	10-B-1
SWC 10-aB6	Genetic studies with nitrogen-fixing organisms.	Beltsville, Md.	Yes	10-D-3, D-5
SWC 10-aB7	The relationship between the soil as the source of nutrients and the ion uptake process in the plant.	Beltsville, Md.	Yes	10-A-1
SWC 10-aB8	Nutrient balance for plant growth as related to soil environment, plant species and variety, and the nature of added nutrient carriers.	Beltsville, Md.	Yes	10-A-1, A-3, B-2
SWC 10-aB9	Development of spectrochemical methods and foliar diagnostic procedures for soil and plant investigations.	Beltsville, Md.	No	
SWC 10-b1	The lime requirements of red and yellow podzolic and related soils.	Thorsby, Ala. Fleming, Ga. Watkinsville, Ga. Oakley, Miss. Holly Springs, Miss. Rio Piedras, P. R. Florence, S. C.	Yes	10-B-2
SWC 10-b2	The fertility requirement of exposed subsoils.	Cartersville, Ga. State College, Miss.	No	
SWC 10-b3	Fertilization for efficient crop production under intensive management.	Thorsby, Ala. Fleming, Ga. Watkinsville, Ga. State College, Miss. Rio Piedras, P. R. Florence, S. C.	Yes	10-A-3

*Approved October 25, 1962

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963 (Continued)

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 10-b4	Developing improved cropping systems for soil conservation.	Fleming, Ga. Watkinsville, Ga. Rio Piedras, P. R. Florence, S. C.	Yes	10-C-2, C-5
SWC 10-b5	Crop residue management and tillage practices for soil conservation and efficient production in the South.	Thorsby, Ala. Watkinsville, Ga. State College, Miss. Rio Piedras, P. R. Florence, S. C.	Yes	10-C-2, C-4
SWC 10-b6	Factors influencing crop rooting development and activity and means of increasing root development in the South.	Auburn, Ala. Watkinsville, Ga. Baton Rouge, La.	Yes	10-B-2, C-3
SWC 10-b7	Integration of improved practices for soil and water conservation in the South.	Fleming, Ga. Watkinsville, Ga.	No	
SWC 10-c1	Moisture utilization in the Corn Belt as influenced by soil fertility level and management practices.	Morris, Minn. Madison, S. Dak.	Yes	10-A-6
SWC 10-c2	Tillage practices and crop residue management for soil conservation and efficient production in the Corn Belt.	Ames, Iowa Morris, Minn. Columbia, Mo. Brookings, S. Dak. Madison, Wisc. LaCrosse, Wisc.	Yes	10-C-1, C-2
SWC 10-c3	Fundamental studies on the mechanism of soil structure formation in the Corn Belt.	St. Paul, Minn.	Yes	10-C-1
SWC 10-d1	Chemical reactions and availability of phosphates in Northern Plains soils as affected by fertilization, soil properties, and management.	Grand Junction, Colo Huntley, Mont. Mandan, N. Dak. Fort Collins, Colo.	Yes	10-A-4, A-5
SWC 10-d2	Soil nitrogen transformations in relation to soil nitrogen maintenance and more efficient use of fertilizer nitrogen in the Northern Plains.	Fort Collins, Colo. Huntley, Mont. Laramie, Wyo. Gunnison, Colo. Mandan, N. Dak. Grand Junction, Colo	Yes	10-A-1, A-2
SWC 10-d3	Fertilizer requirements and fertility status of Northern Plains soils for more efficient crop and forage production.	Huntley, Mont. Newell, S. Dak. Grand Junction, Colo Gunnison, Colo. Mandan, N. Dak. Fort Collins, Colo. Bozeman, Mont.	Yes	10-A-3, A-5, C-5
SWC 10-d4	Improved soil management practices and systems for better conservation farming in the Northern Plains.	Akron, Colo. Fort Collins, Colo. Gunnison, Colo. Sidney, Mont. North Platte, Nebr. Mandan, N. Dak. Newell, S. Dak.	No	
SWC 10-d5	Principles and practices of stubble-mulch maintenance for soil and water conservation in the Northern Plains.	Bozeman, Mont. Akron, Colo. Sidney, Mont. Lincoln, Nebr. North Platte, Nebr. Alliance, Nebr. Mitchell, Nebr.	Yes	10-A-3, C-4, D-1

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963 (Continued)

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 10-d6	Interrelationships of soil and climate as a basis for predicting applicability of research results, soil response to treatment, and crop yields under different levels of management in the Northern Plains.	Akron, Colo. Fort Collins, Colo. Lincoln, Nebr. Laramie, Wyo.	Yes	9-C-7
SWC 10-e1	Interrelationships between soil structure and plant growth.	Woodward, Okla. Cherokee, Okla. Big Spring, Tex. Bushland, Tex. Temple-Riesel, Tex.	Yes	10-C-3
SWC 10-e2	Nutritional requirments for cropland and rangeland in the Southern Great Plains.	Cherokee, Okla. Woodward, Okla. Bushland, Tex. Temple-Riesel, Tex. Weslaco, Tex.	Yes	10-A-1, A-3, A-7
SWC 10-f1	Soil management practices for conservation farming in the Pacific Northwest.	St. Anthony, Idaho Corvallis, Ore. Prosser, Wash. Pullman, Wash.	Yes	10-A-6, C-2, C-4
SWC 10-f2	Chemistry and availability of nutrient elements in soils of the Pacific Northwest.	Corvallis, Ore. Prosser, Wash. Pendleton, Ore.	Yes	10-A-2, A-6
SWC 10-f3	Chemistry and effects of organic matter in soils of the Pacific Northwest.	Corvallis, Ore.	Yes	10-A-2
SWC 10-f4	Microbial equalibria in soils of the Pacific Northwest.	Prosser, Wash.	Yes	10-D-4, D-6
SWC 10-g1	Principles of nutrient uptake and efficient fertilizer use in relation to moisture regime and irrigation practice, soil properties and crop nutrient requirements in the Southwest.	Brawley, Calif. Tucson, Ariz. Logan, Utah	Yes	10-A-1, A-3, C-5
SWC 10-g2	Improvement of soil fertility, crop production and soil and water conservation through the use of fertilizers and soil amendments on rangeland and non-irrigated cropland in the Southwest.	Riverside, Calif.	Yes	10-A-1, A-3
A7-SWC-7	A study of the soil algae of the rice fields and their contribution to the fertility of the soil.	U. of Allahabad	Yes	10-D-6
A7-SWC-17	Iron and molybdenum as plant nutrients.	U. of Lucknow, India	No	
A10-SWC-8	Mode of occurrence of minor elements in sediments and soils: A fundamental study for the understanding of the behavior and distribution of minor elements in soils.	Hebrew U. of Jerusalem	No	
A10-SWC-12	The determination of available micro-elements in calcareous soils.	Hebrew U., Rehovot, Israel	Yes	10-A-6
E21-SWC-2	Fundamental studies of reactions between mineral and organic components in soil.	College of Agric., Wroclaw, Poland	No	
E21-SWC-7	Distribution of micronutrient elements among soil minerals.	Institute of Soil Sci. & Plant Cultivation, Pulawy, Poland	Yes	10-A-6
E21-SWC-3	Studies on the variability and genetics of Rhizobium.	M. Curie-Sklodowska U., Lublin, Poland	Yes	10-D-5

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SWC 11	Soil, water, and plant relations as they affect use of land and water resources.	Beltsville, Md.		
SWC 11-a1	The energy budget at the earth's surface.	Ithaca, N. Y.	Yes	11-B-1
SWC 11-b1	Modification of soil surface structure and crop geometry to beneficially influence climatic conditions in the South.	Thorsby, Ala.	Yes	11-B-7, C-1
SWC 11-b2	Plant factors influencing transpiration in the South.	Watkinsville, Ga. Florence, S. C.	Yes	11-B-4, B-7, C-2
SWC 11-b3	Gaseous losses of nitrogen under field conditions in the Southern States.	Thorsby, Ala.	No	
SWC 11-b4	Reduction of strontium-90 by crops.	Ft. Lauderdale, Fla. Watkinsville, Ga. Florence, S. C.	No	
SWC 11-c1	Soil moisture-plant growth relationships.	Urbana, Ill.	Yes	11-A-2, B-1, B-4, C-2
SWC 11-c2	Climatic influence on water use and crop performance in the Corn Belt region.	Morris, Minn. Urbana, Ill.	Yes	11-B-1
SWC 11-c3	Soil moisture flow problems and solutions in the Corn Belt region.	Columbus, Ohio Urbana, Ill.	Yes	11-A-2, A-3
SWC 11-d1	Principles affecting soil structure stability and its effect on aeration intake, transmission and storage of water on irrigated lands in the Northern Plains.	Fort Collins, Colo.	No	
SWC 11-e1	Understanding and improving soil-plant-atmospheric relationships for more efficient utilization of water.	Big Spring, Tex. Temple-Riesel, Tex. Manhattan, Kans. University Park, N.M. Weslaco, Tex. Bushland, Tex.	Yes	11-A-2, A-4, B-2, B-5, B-6
*SWC 11-13 (g1)	Physical processes affecting soil water and their relationship to physiological functioning of plants.	Brawley, Calif. Logan, Utah	Yes	11-A-1, A-2
SWC 11-gF1	Physical properties and kinetics of change of of the physical properties of water in soil-water systems.	Riverside, Calif.	Yes	11-A-1, A-2
SWC 11-gG1	Uptake and disposal of water by plants in an arid climate.	Tempe, Ariz.	Yes	11-A-1, B-3, B-4

*Approved April 22, 1963

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 12	Nutrition of animals as affected by properties and characteristics of soils and plants.	Beltsville, Md. Ithaca, N. Y. & selected states		
SWC 12-aA1	Studies of the effects of soil and geological conditions on the composition of forages and other crops in relation to nutritional troubles in animals.	Ithaca, N. Y.	Yes	12-A
SWC 12-aA2	Effect of environment, soil type, and soil management on the nutritive quality of crops as measured by animal growth, health, and reproduction.	Ithaca, N. Y.	Yes	12-A
SWC 12-aA3(c)	Micronutrient elements of soils and plants in relation to certain endemic nutritional diseases of animals.	Ithaca, N. Y. Corvallis, Ore.	Yes	12-A
SWC 12-aA4	The role of mineral elements, enzymes, nucleic acids and other factors in the biosynthesis of proteins.	Ithaca, N. Y.	Yes	12-C
SWC 12-aA5	Chemical reactions of micronutrient cations with clay minerals and plant extracts.	Ithaca, N. Y.	Yes	12-D
SWC 12-aA6	Toxicities in food and forage plants with particular reference to nitrates and certain mineral elements.	Ithaca, N. Y.	Yes	12-A
SWC 12-aA7	Effect of plant nutrients and other mineral elements on the amino acid and protein content of food and forage plants.	Ithaca, N. Y.	Yes	12-B, C
SWC 12-aA8	The role of mineral elements in the formation of the organic matrix of bone.	Ithaca, N. Y.	Yes	12-B

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
SWC 13	Fertilizer investigations: resources, production, and improvement.			
SWC 13-aC-1	Consumption of commercial fertilizers in the United States.	Beltsville, Md.	Yes	13-E
SWC 13-aC-2	Sources and trends in the production and use of fertilizers and plant nutrients.	Beltsville, Md.	Yes	13-E
SWC 13-aC-3	Fertilizer resources and development in foreign countries.	Beltsville, Md.	Yes	13-E
SWC 13-4 (aC4) Rev.*	Standardization of specifications and test procedures for marketed fertilizers, liming materials, and other soil amendments.	Beltsville, Md.	Yes	13-C
SWC 13-aC-5	Preparation of radioactive fertilizers.	Beltsville, Md.	Yes	13-B
SWC 13-aC-6	Effect of physical properties of nutrient materials on the granulation of fertilizer mixtures.	Beltsville, Md.	Yes	13-B
SWC 13-aC-7	Fertilizer as a vehicle for soil applications of growth regulators and herbicides.	Beltsville, Md.	No	
SWC 13-aC-8	Suitability of nitrogen materials for fertilizer use.	Beltsville, Md.	Yes	13-A
SWC 13-aC-9	Separation of nitrogen components of fertilizers.	Beltsville, Md.	Yes	13-A
SWC 13-aC-10	Inhibitors of urea hydrolysis.	Beltsville, Md.	No	
SWC 13-aC-11	Physical characterization of phosphatic fertilizer materials.	Beltsville, Md.	Yes	13-A
SWC 13-aC-12	Nutritive value of water-insoluble phosphates in multinutrient fertilizers.	Beltsville, Md.	No	
SWC 13-13 (aC13)**	Chemical composition and physical characteristics of agricultural limestone.	Beltsville, Md.	Yes	13-A
SWC 13-aC-14	Utilization of flue dust from cement kilns as a liming material and fertilizer.	Beltsville, Md.	Yes	13-A
SWC 13-aC-15	Development and evaluation of primary carriers of zinc for use in crop production.	Beltsville, Md.	Yes	13-A
SWC 13-aC-16	Amounts of nitrogen, phosphorus and potassium applied to economic crops in 1959.	Beltsville, Md.	Yes	13-E
SWC 13-17 (aC17)***	Development of procedures for determining aluminum, iron, phosphorus, manganese, and titanium in agricultural liming materials.	Beltsville, Md.	No	

*Approved March 25, 1963
**Approval for discontinuance received January 17, 1963
***Approved April 24, 1963

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